RULES

Books and periodicals may be used in the Society rooms by members and friends.

Members may borrow books for home use—with the exceptions noted below—but no one shall have more than four books at any time, or keep any book more than two weeks.

Volumes belonging to a set—such as volumes of bound periodicals and of proceedings or transactions of societies—and such other books as the Board of Government may designate, may be taken from the rooms for a limited time only, by special arrangement with the attendant. They shall be subject to recall at any time.

There shall be no immediate renewal of any book on its return to the library.

A member borrowing a book shall at that time give a receipt therefor.

A fine of one cent per day per volume shall be charged for over-time, and must be paid before the delinquent can take any more books.

Hand books, indexes, current numbers or unbound files of periodicals, books belonging to the Clemens Herschel Special Library, and new books not yet placed on the regular shelves must not be taken from the rooms.

Books of unusual value are marked with a star (*), and must not be taken from the rooms, except by written permission from the Librarian, to be filed by the attendant.

Any person mutilating or losing a book shall pay for the damage, or replace the book.

Any one who violates the above rules may, upon written request from the Librarian to the Board of Government, be debarred from the privileges of the library for such time, not less than three months, as the Board of Government may determine.

(Revised June 16, 1915.)

JOURNAL

OF THE

New England Water Works

ASSOCIATION.

VOLUME IV.,

September, 1889, to June, 1890.

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BOARD OF EDITORS.

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INDEX.

NEW ENGLAND WATER WORKS ASSOCIATION.

ORGANIZED 1882.

Vol. IV. Sept., 1889. No. 1.

This Association, as a Body, is not responsible for statements or opinions of any of its members.

PROCEEDINGS OF THE EIGHTH ANNUAL CONVENTION.

FALL RIVER, MASS., June 12, 13, 14, 1889.

WEDNESDAY, June 12, 1889.

AFTERNOON SESSION.

The Convention was called to order at 3 o'clock, P.M., by President Nevons. Prayer was offered by the Rev. W. W. Adams. Alderman Charles J. Holmes, representing the Mayor, then addressed the Convention, as follows: —

ADDRESS OF WELCOME BY ALDERMAN HOLMES.

Mr. President and Gentlemen of the New England Water Works Association, — In the absence of the chief executive it falls upon me to welcome you to our city. I am obliged to be brief in my remarks on account of other engagements, but you will excuse me, especially as I understand you yourselves propose to do most of the talking during your sessions here. I will only say that your fame has preceded you, and we expect a good deal from you. One of the greatest problems for our municipalities is perhaps that of getting good water, taking care of it while we have it, and disposing of it when we are through with it. This is a subject to which you have all especially addressed yourselves, and it is one in which we are all interested; and I hope that the Convention which you are to hold here will be profitable to us as well as to you, and that your stay here will be agreeable. I will now leave your President to direct the business of your Convention as he may see fit. [Applause.]

RESPONSE BY PRESIDENT NEVONS.

Allow me, sir, in behalf of the New England Water Works Association, to thank you, and through you the members of your city government, for your cordial welcome to us. We are a body of practical men, met together seeking information, by social intercourse and exchange of thought, on subjects of great importance in relation to questions which arise in every city and town that has a water-supply or is looking for one. We have come to your city from widely separated homes and fields of labor. When our membership roll is called the

answer comes from the Provinces, the rocky shores of Maine, the granite hills of New Hampshire and Vermont, from on through the New England States to the golden West, down through the sunny South; and across the water from the land of the thistle and the heather, from Scotland's famous old city of Glasgow, we are still honored with the answer, "Here." And, sir, we expect our membership to be as widely extended as the Yankee jack-tar said that Uncle Sam's dominions were, after listening to the English tar's boast of the Queen's dominions, and that the true bounds of our membership will be "the aurora borealis and the south pole." [Laughter and applause.]

Again thanking you for the courteous words you have spoken, I will add, we extend to the members of your city government a hearty invitation to be present at our deliberations while we are in your city, and express the hope that none of the good people of Fall River will ever regret that the New England Water Works Association held its Eighth Annual Convention here.

On motion of the Secretary, the reading of the minutes of the last meeting was dispensed with, they having already appeared in print.

ELECTION OF MEMBERS.

The Secretary presented the following names of applicants, all of whom had been considered and approved by the Executive Committee : —

FOR RESIDENT ACTIVE MEMBERSHIP.

J. White Belcher, Water Commissioner, Randolph, Mass.
L. M. Hastings, City Engineer, Cambridge, Mass.
Wm. F. Harbach, Water Commissioner, Newton Centre, Mass.
Augustus W. Locke, Civil Engineer, North Adams, Mass.
E. T. Wiswall, Water Commissioner, West Newton, Mass.
Horace H. Lowe, Superintendent, Clinton, Mass.
John F. Plunkett, Registrar, Marlborough, Mass.

FOR NON-RESIDENT ACTIVE MEMBERSHIP.

Carroll Ph. Bassett, Civil Engineer, Newark, N. J.
C. Emmett Bennett, Superintendent, Ticonderoga, N. Y.
H. M. Fales, Superintendent, Tonawanda, N. Y.
H. W. Greetham, Local Manager, Orlando, Fla.
E. H. Keating, City Engineer, Halifax, Canada.
W. H. Laing, Superintendent, Racine, Wis.
Robert K. Martin, Chief Engineer, Baltimore, Md.
G. A. Roullier, Superintendent, Flushing, N. Y.

FOR ASSOCIATE MEMBERSHIP.

Walter B. Nye, "Warren Filter," Boston, Mass.
Samuel L. Monson, "United Brass Co.," New York City.
Galvin Brass and Iron Co., "Valves, Hydrants, etc.," Detroit, Mich.
Nathl. C. Locke, "Damper Regulator," Salem, Mass.
A. W. Worthley, "American Frost Meter Co.," Boston, Mass.

On motion of Mr. Glover, the Secretary was requested to cast the ballot of the Association in favor of the admission of all the applicants, and he having done so, they were declared elected.

ADDRESS OF THE PRESIDENT.

President Nevons then addressed the Association as follows: —

Gentlemen of the New England Water Works Association, — We have met to-day, for the eighth time, in Annual Convention.

We have held five meetings since our last annual meeting in Providence. The first of these was a field day at Cambridge, in September. The weather was discouraging in the morning, but it cleared away toward noon. As about one hundred members had arrived, the full programme was carried out, and a very enjoyable day was spent in visiting the water works, the Stony-brook dam, and other places of interest.

The other four meetings were held at Young's Hotel, in Boston, in December, January, February, and March. The average attendance at these was about seventy-eight, showing an increasing interest of the members and friends of our Society. There has been no lack of subjects, or of those ready to discuss them. The special papers which have been read have received favorable notice from those by whom we naturally desire to be recognized. They have tended to increase our reputation as a live Association, and one whose influence is being felt in the important department we represent. The more informal discussion of these papers, and the meetings mainly given up to short addresses on a great variety of topics connected with water works, have also been solid, and exceedingly helpful.

The Association is to be congratulated on its acquisition of many valuable new members during the year past, and on the prosperous state of its treasury, of which our Secretary and our Treasurer will speak in detail.

Your President has ventured to make a new departure in two respects. We are taught and recognize the fact that no one should ever enter upon any great or important undertaking without first invoking a blessing from Deity; and also that the harmony of music begets harmony of feeling among men in all stations of life. One of the changes made by your President during the past year has accordingly been the introduction of music into our meetings, in order to give variety and add spice to the exercises. He was delighted to have the Association approve of this, and adopt it as a stated feature of our gatherings. The other change has been the offering of grace at our banquets, or of a brief prayer at our more formal meetings. Surely our deliberations are of enough importance to the public health and the public welfare for us to ask God's blessing on them, and our pleasure at our gatherings deserves the return of thanks to the great Giver who sendeth rain from heaven, and fruitful fields, filling our hearts with joy and gladness. May I be allowed to express the hope that this precedent, also, will be followed in the time to come.

Now, lest what I have said should seem like glorying, let me say that the past year has been a disappointment to me. I anticipated a great deal of labor and discomfort in the performance of my duties. But thanks to your courtesy and

generosity in overlooking what was lacking in me, and to your responsiveness and hearty coöperation, and thanks especially to the associated officers, the Executive Committee, and those who have responded so willingly to calls made on them for service, I have had my duties much lightened, and have found great pleasure in the service. In short, the progress which has been made has been largely due to you, while the honor which you have conferred on me is one which I shall long remember.

I should do injustice to my own feelings if I failed to return special thanks to our faithful and untiring Secretary for his uniform kindness and courtesy in cheerfully meeting all of the perplexing duties connected with his office. I dare say the question has occurred to you, as it has to me, whether, in view of the growth of the Association, and of its manifold and important relations, the time has not arrived for us to employ a Secretary to give his entire time to the Association's work; and, if so, whether we can find a man so well qualified for precisely this position as our present Secretary. It gives me pleasure to add to my thanks to him, the more general but equally true statement, that there has been the best of harmony in our intercourse as officers and members.

But let us take a longer retrospect. Let us look back, not over the pleasant year just closing, but over the eight years since the New England Water Works Association was organized. Eight years are a long time for men to be in school or at college. Are we better men in the places we occupy, and in the communities in which we live? Have we learned all there is to be learned in our calling, or have we exhausted the subjects relating to it so that there is nothing left for us to learn? I think, on the contrary, that our experience in our work, and our opportunities in this Association, have only opened wider fields of inquiry, and extended, to our conception, the bounds of that which we desire to master.

But he who is desirous of obtaining information should be ready in return to impart of his experience and thought, thus broadening knowledge by a mutual exchange of it. The advancement made has been great, far beyond the anticipations of the few who assembled at Young's Hotel eight years ago and organized this Association. We were isolated at that time. But few of our number had been educated for this peculiar vocation. We were meeting troubles and perplexing questions, and were so absorbed in them that we thought we were the only ones who had difficulties. And with theory for a starting-point we were in the way of learning well, at least; but when we backed it up with practice, and came out about right, perhaps some of us even thought we knew it all. But the eight years of social intercourse and personal interchange of thought and experience (the unwritten work of our meetings, and sometimes I think the best part) have changed all that. I refer to when two or more get together and relate some instance, or express an idea, and it is taken up and discussed, and some one of the number gets a thought, and, working it out, gets from it important results.

The systems and methods of practice on the different water works of New England, and in fact of the United States, are an open book to all who are interested. The subjects which have been brought before the Association and discussed have been those of the greatest importance in their relation to the economy and management of water works; and though mainly technical, they have occasionally branched out, as should sometimes be the case, into broader fields. Let

me refer, for an example, to a paper read during the past year, on "Water in some of its Higher Relations," commenting on which, as printed in our JOURNAL, one of the Boston papers said that it "treats the subject entirely outside of its technical limitations, and in relation to the world and life at large," and adds, "whoever wishes to read one of the freshest literary essays of the season will hunt up this periodical." I instance this to emphasize an element which, as it seems to me, ought occasionally to be introduced into our meetings and into our private studies, in order that we may be broader than merely technical men. I wish that at least once each year we might have an essay, or an oration, or lecture, reaching thus broadly out into the great world of fact and of life, of which our greatest "works" and achievements are only a tiny part. But, to go back to what I was saying, the subjects discussed by the Association are so many and varied that they cannot be referred to at this time. They will be found recorded in the JOURNAL of the Association, which has a wide circulation, and is a very important record.

I think I may say of our Association, that it is recognized as an institution of importance by the best business and professional men. There is not a city or town having water works but has been benefited by it. It is, therefore, well for us to leave our fields of labor on these beautiful June days, and assemble together, and lay broad and comprehensive plans for the future, never losing sight of the fact that we are a body of practical business men, — representatives of one of the most important departments connected with any city or town. Let us be social and have a good time, but let us never forget the dignity due to such a representation. As business men, in commencing a piece of work, we have a starting-point. Let us think out carefully the work before us, that we may avoid mistakes from beginning to end.

In conclusion, let me thank you for your attention, and allow me to urge upon you, one and all, to guard with jealous care the interests of the Association, that it may attain from year to year a higher and yet higher standing and usefulness. [Applause.]

REPORT OF THE SECRETARY.

Secretary Coggeshall then read the following report: —

NEW ENGLAND WATER WORKS ASSOCIATION,
OFFICE OF THE SECRETARY,
NEW BEDFORD, June 3, 1889.

Gentlemen of the New England Water Works Association, — Your Secretary herewith presents his report for the year ending June 1, 1889: —

A year ago the membership of this Association was as follows, viz.: —

Active members	181
Honorary members	3
Associate members	54
Total	238

During the year there has been a loss of nine members from the following stated causes: —

Deceased	3
Resignations received	3
Suspended for non-payment of dues	3

Fifty-one applications for membership have been presented for your consideration, all of which have received favorable action.

Our total membership is now: —

Active members	209
Honorary members	4
Associate members	64
Total	277

The net gain for the year has been 41 members.

Your Secretary has made 324 collections, which may be thus itemized: —

From Advertisements	$1,130 00
Initiation fees	287 00
Dues	674 50
Sale of transactions	59 88
Total	$2,151 38

All of which has been paid to the Treasurer.

Respectfully submitted,

R. C. P. COGGESHALL,

Secretary.

On motion of Mr. Clark, the report was accepted and placed on file.

A GAVEL PRESENTED TO THE ASSOCIATION.

The President called the attention of the Convention to a gavel which had been sent to him by Mr. J. M. Diven, Secretary of the American Water Works Association, and which, in behalf of the donor, he presented to the Association.

On motion of Mr. Brackett it was voted to accept the gift, and the Secretary was directed to convey the thanks of the Association to Mr. Diven.

REPORT OF THE TREASURER.

Mr. Glover then read the report of the Treasurer, which was as follows: —

Report of Albert S. Glover, Treasurer,

TO THE

NEW ENGLAND WATER WORKS ASSOCIATION.

Gentlemen, — I have the honor to herewith submit a record of my doings as your Treasurer, for the year ending with date: —

1888.	RECEIPTS.	
June 12.	Balance on hand, beginning of year,	$888 31
July 24.	Interest received,	30 19
Oct. 19.	Received from R. C. P. Coggeshall, Secretary,	300 00
1889.		
Jan. 14.	" " " "	400 00
May 22.	" " " "	1,000 00
June 3.	" " " "	451 38
" 3.	" " interest,	22 50
	Total receipts,	$3,092 38

1888.	EXPENDITURES.	
June 14.	Paid R. C. P. Coggeshall, for Association expenses at Providence,	$25 00
July 10.	" J. P. Bacon, reporting meeting,	59 00
" 30.	" Edwin Darling, for Association expenses at Providence,	41 00
Aug. 1.	" American Photo. Co., for cut,	1 50
" 2.	" C. H. Stacy, postage and telegrams,	10 84
" 27.	" Albert S. Glover, for sundry payments on account of advertisements,	53 60
" 27.	" Heliotype Printing Co., for heliotypes,	17 50
Oct. 18.	" The Day Co., printing JOURNAL, etc.,	176 03
" 18.	" W. H. Richards, postage, expressage, etc.,	7 41
" 22.	" Mercury Publishing Co., printing,	59 40
Nov. 17.	" "Railroad Gazette," cut,	2 05
" 17.	" H. D. Utley & Co., envelopes, etc.,	6 15
" 17.	" W. H. Richards, travel, expressage, etc.,	8 57
Dec. 20.	" Heliotype Printing Co., heliotypes,	22 50
" 20.	" F. L. Pratt, music furnished December meeting,	15 00
" 20.	" J. R. Whipple, December meeting at Young's Hotel,	21 50
1889.		
Jan. 15.	" J. R. Whipple, January meeting at Young's Hotel,	18 70
" 29.	" The Day Co., printing JOURNAL, etc.,	104 50
" 29.	" F. L. Pratt, music furnished at January meeting,	15 00
Feb. 3.	" W. H. Richards, envelopes, clerical assistance, travel,	27 01
" 13.	" J. R. Whipple, February meeting at Young's Hotel,	26 00
" 13.	" F. L. Pratt, music at February meeting,	15 00
Mar. 13.	" J. R. Whipple, March meeting at Young's Hotel,	11 40
" 13.	" F. L. Pratt, music at March meeting,	15 00
" 30.	" P. O'Brien & Son, flowers at Mr. Barbour's funeral,	6 00
" 30.	" American Photo. Co., cut diagram,	7 50
" 30.	" Walter Rogers & Co., reporting January meeting,	30 75
" 30.	" Walter Rogers & Co., reporting February and March meetings,	37 50
	Carried forward,	$841 41

		Brought forward,	$841 41
May 1.	Paid	W. H. Richards, for postage, expressage, clerical assistance, etc.,	13 98
" 27.	"	R. C. P. Coggeshall, for postage, telegrams, and expressage,	101 16
" 27.	"	R. C. P. Coggeshall, salary as Secretary,	300 00
" 27.	"	Edwin Dews, envelopes, etc.,	11 80
" 27.	"	Albert S. Glover, for services as business manager of Association JOURNAL, as per vote of executive committee,	300 00
" 27.	"	Mercury Publishing Co., for letter-heads, circulars, envelopes, printing, etc.,	89 00
		Total expenditure,	$1,657 35

To this, however, should be added the amount of the following-named bills, all of which were duly contracted and have been duly approved, but which were received by the Treasurer too late for payment before the meeting: —

The Day Co., for printing No. 3 of the JOURNAL, etc.,	$237 80	
" " " " " " 4 " " "	197 55	
The Heliotype Printing Co., heliotypes for No. 4 of JOURNAL,	35 00	
		470 35
Making the actual expenditure for year,		$2,127 70

RECAPITULATION.

Amount received by Treasurer during year,	$3,092 38
" paid " " " "	2,127 70
Leaving balance on hand,	$964 68

Respectfully submitted,

ALBERT S. GLOVER,
Treasurer.

FALL RIVER, MASS., June 12, 1889.

On motion of Mr. Coggeshall the report was received and placed on file. Mr. Glover stated that the Finance Committee, a report from which was the next business in the regular order, had not had a meeting and were therefore not prepared to report.

COMMUNICATIONS.

The Secretary read letters from Chester W. Kinsley, Rev. D. N. Beach, J. Herbert Shedd, and Geo. P. Westcott, regretting their inability to be present during the Convention.

REPORT OF COMMITTEE ON BADGES.

Mr. Darling, chairman of the Committee on Badges, exhibited a sample of a badge, being a button bearing the letters, "N.E.W.W.A.," which the committee recommended for adoption by the Association. Mr. Osborne moved to accept the report and adopt the recommendation. Mr. Brackett suggested it would be well to postpone action until the members had had opportunity to inspect the badge. Mr. Darling said he had no objection, and on a motion of Mr. Brackett the matter was laid on the table.

COMMITTEE TO NOMINATE OFFICERS.

On motion of Mr. Darling, the following committee was appointed by the President to nominate officers for the ensuing year: Messrs. Brackett, of Boston; Hall, of Quincy; Holden, of Nashua, N. H.; Kieran, of Fall River; and Rogers, of Salem.

COMMITTEE ON BLUE PRINTS.

On motion of Mr. Coggeshall (amended by Mr. Richards), the following committee was appointed by the President to attend to the distribution of blue prints: Messrs. Richards, of New London, Conn.; Cook, of Woonsocket, R. I.; Robertson, of Fall River; and Wilder, of Woodstock, Vt.

The next business, in regular order, was the report of the Committee on Pipe Joints and Special Castings. Secretary Coggeshall explained that there had been a misunderstanding as to the appointment of the committee, and on his motion the subject was passed.

Supt. George A. Stacy, of Marlboro', Mass., then read a paper entitled "Hydrants," which was discussed by Messrs. Richards, Brackett, Darling, and Clark.

HOW TO SET HYDRANTS TO PREVENT FREEZING.

The President. — We will now take up, gentlemen, the first on our list of general topics, "Suggestions as to the best method to set hydrants to prevent freezing," and I will first call on Mr. Rogers, of Salem.

Mr. Rogers. — What I have to say follows in the line of the paper which has been read, and the suggestions which have been made, although I feel as though I can hardly add anything to what we have heard thus far. I have an idea that there is no rule, except a very general rule, that can be given for setting hydrants; and that is, that they should be set below the point of frost. Of course, if that were possible in all cases, that would be the only necessary thing to do to prevent them from freezing, or at least to prevent a large part of the trouble. Of course there are cases where it is difficult to set them so deep, but I think it is better to go to considerable expense to do it than it is to place a hydrant in a position where it is bound to be a nuisance and is pretty sure to call for extra expense in maintaining it. I presume if there is a right understanding between the water department and the city or town authorities having charge of the location of hydrants, if there is a right understanding between the fire department and the water department, it can be satisfactorily arranged to have the position of

a hydrant vary from the specified number of feet, if by so doing a point can be reached at which it will, perhaps, be possible to place it more easily and at less expense. Of course it costs something to take up rock, but it is better to do it and thereby get the hydrant down deep enough, than it is to place the hydrant where it is liable to freeze. I think more thought has been given to this subject within a few years than was formerly given to it. Four feet, four and a half, or even five feet may not be deep enough to be beyond the reach of frost. As the result of my experience, which has been supplemented the last year or two by my observations down in the State of Maine and in New Brunswick, where the frost goes deeper than in Massachusetts, I have come to the conclusion that in some localities the limit of safety is at least six or six and a half feet. On works where I have been recently, I have found that hydrants which have been carelessly placed by contractors have frozen. In some places on the St. Croix river, for instance, hydrants froze under circumstances which I have no doubt could have been prevented by proper care at the time of setting. If it is concluded to be desirable to place them above the frost line, they can be protected by packing, and we have made use of tan-bark with good effect. I don't know as I can add anything more, and will close by repeating that, as the result of my experience, I have come to the conclusion that as far as possible hydrants should be set below the frost line.

Mr. Darling. — Had those hydrants which you spoke of as having frozen just been laid, or had they been laid a year?

Mr. Rogers. — They had been laid one year, but the first winter was not very severe. They were set in a very clayey soil, perfect brick clay.

Mr. Darling. — I have found the first winter after laying water-pipes, before the ground became fully settled, the frost would penetrate into the comparatively loose earth much deeper than it would after the earth became solidly settled. I have noticed that in several places where new works have been built.

Mr. Keating. — I do not know that I can add very much to what has been said on this very interesting subject. I think the packing has a great deal to do with preventing freezing. I have been connected with works in a place where the soil is somewhat similar to what has been described, a very hard clay. In those works the hydrants were designed with a drip, but there were no sewers in the place. The first winter there was a good deal of trouble, and the hydrants had frequently to be pumped out. In some of the worst cases I had trenches dug to meet the hydrants, and filled the trenches up with stones, hoping the water could be run off in this manner; but the soil was of such a nature I found the trenches would fill with water, and eventually all the hydrants had to be plugged and pumped out. They were set five feet under ground. After they were plugged and the water was pumped out, we never had any further trouble with them. We used ashes for packing, and I think the frost in that place — it was in Nova Scotia — goes as deep as in any town in New England. I don't know that it is necessary to go very much deeper than five feet; I never found it so, — that is, to the top of the pipe, even though the frost may penetrate to a greater depth; that is, if you are careful about packing the hydrants. I have known the frost to go six feet and a half, and the hydrant, — where it was properly packed, — not to be affected.

I may also say that I have had some experience with hydrants being used for

general purposes, for street sprinkling, and for flushing sewers, etc., by the different departments. It is a difficult matter to deal with in some towns, where it would involve an enormous expense to put in the number of standpipes which would be required. The city of Halifax is built on rock, and of course it costs a great deal of money to lay pipes. We are as careful as we can be in selecting the men who use the hydrants, and I cannot say we have experienced very much trouble when the men have been careful about using them, though some of the hydrants have been damaged by careless handling.

Mr. Holden. — I have had very little trouble with frozen hydrants, although I have been in places where the frost penetrates about as deep as anywhere in New England. When I set a hydrant I use thirty or forty brick, and build up a loose wall around the front and sides of the hydrant, which serves as an air-chamber, and it has always worked well. Winter before last, when my neighbors were complaining of frozen hydrants, I don't know that I had one freeze all winter. Whether it was owing to the nature of the soil or to this loose chamber around the hydrants, I cannot state. In running to a hydrant from the street main, I am always careful to have the hydrant on the short side of the street, if possible; that is, on the same side the main lies; and whenever there is a ledge, I always cover the supply running from the main to the hydrant with a plank. That serves to make a sort of an air-chamber, and it has always kept out the frost. I don't know whether that would work well in other cities, but it has worked well with me.

Mr. Stacy. — I have often thought it would be a pretty good idea if some of our smart hydrant makers would design some automatic plug or drip which could be worked at or near the surface. When I have a chronic case of a hydrant troubled with surface-water, I plug it up, as my friend on the left (Mr. Clark) does, though I don't do the same as he does in the spring, — open it again, but I let it stay there. Whenever the hydrant is used I pump it out. We build a well with small cobble-stones around our hydrants when we set them, and sometimes it does a great deal of good and sometimes it doesn't. The only effect it has on some of our hydrants is to give a chance for a little more water to collect around the foot of the hydrant from the outside; there can't but a little get from the hydrant out of the drip. When I find such a case, I plug the hydrant and let the plug stay in. I don't believe in trying hydrants much, if they are all right, in cold weather, but I believe we ought to know whether they are right or not; and if they were so constructed we could find out whether they are all right or not without disturbing them, I think it would be a good thing, and we would be safe in trying them. There are a good many places, probably, where there is trouble from surface-water, and some places where it is chronic, and then of course all there is to do is to plug up the hydrants. It would be very nice if we had a plug or drip that could be worked from the surface or near the surface. Another thing which has occurred to me is, that where a hydrant has a good drip, it would ensure its working if there was not only an automatic drip, but an automatic vent at the top that would open when the drip opened, and close when it closed. In some cases I think that would obviate a frozen hydrant by giving a chance for the air to get in. Some of these hydrant makers make their fits so nice that there is no chance whatever for air to get in.

Mr. Parker. — In St. Paul they set many of their hydrants in brick vaults.

They build a brick vault around the hydrant and have a cast-iron cover to it, and the vault is large enough so a man can go down into it and attend to the drip, or make any necessary repairs without any excavation. I suppose that plan was adopted because they have a great deal of ledge there. It struck me at the time that it was a very good idea, but rather expensive.

Mr. Eglee. — I should like to mention a practice which prevails in the city of Rochester. In that town the hydrant is packed with masonry, going around the hydrant on both sides and leaving only the joint open. Inserted in the masonry is a tile pipe which leads from the drip to at least fifteen feet away and terminates in a stone well; and where there is surface-water in the ground it is let into the sewer.

Mr. Winslow. — My experience has been very small in connection with this matter. I have some hydrants which are set in very wet ground where the water stands almost all the time. One hydrant in particular has been a puzzle to me. In years before it would freeze every winter, but a year ago last winter it did not freeze. During the coldest of the weather that year the chief engineer of the fire department and myself inspected the hydrants which we thought were most liable to freeze, and among others we inspected that and were surprised to find it free, not a particle of ice in it. This last winter it caught slightly; not enough so but what it could be opened easily. All the others went through the winter all right except one. That was one which had been lowered, on account of its having been frozen before, a foot, so it was six feet and a half from the top of the ground to the top of the pipe. That hydrant was tried one day with the others and found to be all right; but the next day there was a fire and it became necessary to use that hydrant, and we couldn't get the hydrant open. I told the engineer after that I thought the best thing we could do was to let the hydrants alone. Our practice has been to put the hydrants below frost line, and we have found we would have no trouble in gravel if the pipe was five feet deep; in sandy soil we put them down six feet and six and a half, and we have no trouble whatever with frozen hydrants, excepting in the two or three cases I have mentioned. My method of preventing hydrants from freezing is to put them below the frost line.

Mr. Clark. — Before this subject is left I would like to make an inquiry. I have seen in the papers a cut representing two pipes running from the main to the hydrant, the idea apparently being that the water would flow from the main up to the hydrant, and then back again; and I would like to know if any gentleman here has had any experience with an arrangement of that kind.

Mr. Brackett. — I have had no experience with it; but there was exhibited at the last annual convention a model of a hydrant connected with the main by two pipes, and in the model the water circulated in the pipes. Whether it would in practice I couldn't say. It would seem to me that a much more economical way of preventing the freezing of a hydrant would be to add one or two feet to the length of the hydrant-barrel rather than to add fifteen feet to the connection pipe, with the double branch which would be necessary at either end. In fact, I would emphasize that point of making the hydrant-barrels long enough to carry the hydrant below the frost. All of the hydrants in Boston, except the Lowry hydrants, which are set on the main, are now set lower than the main.

Mr. Conant. — Most of the gentlemen who have spoken here to-day have

related their experiences in connection with public works. I am running a private company. The town has a fire department, and I would like to inquire if there is anything that can be done to keep the firemen away from the hydrants, or to regulate things so they will let them alone except when they are required for fire purposes? They seem to delight, especially if they have had a little something besides water, to take a hydrant-wrench and go fooling around the hydrants; and they will open them, and won't stop for them to drip, and consequently we have had trouble. In fact, we have had much more trouble in keeping the engineers from opening the hydrants than from any other one thing. If I say anything to them they will retort, "Oh, you are afraid of our wasting the water," and they are very independent. Of course we desire merely to protect the property of the town, but we can't help their using them.

Mr. Darling. — I recommend you have a prohibitory law passed there. [Laughter.]

Mr. Brackett. — In Boston the firemen never open a hydrant except in case of fire. When they wish to give an exhibition of the department, they obtain permission of the water department to use the hydrants.

On motion of Mr. Coggeshall the Convention then adjourned to 7.30 P.M.

EVENING SESSION.

In the evening, Prof. J. E. Denton, of the Stevens Institute of Technology, Hoboken, N.J., addressed the Association on "The best economy attained by the modern high-expansion type of pumping-engine compared with the best record of Cornish pumping-engines during the time of Watt, as recorded by the Wicksted experiments."

The lecture was illustrated by lantern views.

Thursday, June 13.

MORNING SESSION.

The Convention was called to order by the President.

Superintendent Charles E. Bolling read a paper describing the water works of Richmond, Va., which was discussed by Mr. Clark, President Nevons, and Mr. Babcock.

Superintendent George F. Chase, of Taunton, Mass., then read a paper entitled "Friction in the collection of meter rates."

Water Registrar Albert S. Glover, of Newton, Mass., read a paper entitled "Water-works Records."

Mr. Coggeshall, in behalf of Superintendent Kieran, invited the members of the Association to a horse-car ride about the city at the close of the morning session.

Mr. Coggeshall. — At a meeting of the Executive Committee yesterday it was voted to recommend to the Association the adoption of the following order: —

"*Ordered*, That the Executive Committee recommend to the Association that the junior editor be paid a salary of $300 for his services during the coming year, such salary to include travelling expenses."

On motion of Mr. Hall the recommendation was adopted, and it was voted to pay a salary of $300 to the junior editor.

ELECTION OF OFFICERS.

The committee appointed to nominate officers presented the following names for the consideration of the Association: —

President. — Dexter Brackett, Boston.

Vice-Presidents. — W. M. Hawes, Fall River; W. B. Sherman, Providence; Geo. P. Wescott, Portland, Me.; H. G. Holden, Nashua, N. H.; W. H. Richards, New London, Conn.; F. W. Wilder, Woodstock, Vt.

Secretary. — R. C. P. Coggeshall, New Bedford, Mass.

Treasurer. — Hiram Nevons, Cambridge, Mass.

Senior Editor. — Desmond Fitz Gerald, Boston, Mass.

Junior Editor. — Albert S. Glover, West Newton, Mass.

Executive Committee. — Frank E. Hall, Quincy, Mass.; Edwin Darling, Pawtucket, R.I.; H. W. Rogers, Salem, Mass.

Finance Committee. — H. F. Whittier, Lawrence, Mass.; G. E. Winslow, Waltham, Mass.; F. A. Andrews, Nashua, N. H.

On motion of Mr. Darling the Secretary was instructed to cast the ballot of the Association for the gentlemen whose names had been read, and he having done so, the President declared them elected officers for the ensuing year.

THE PLACE FOR THE NEXT ANNUAL CONVENTION.

Mr. Brackett. — I think it would be well for the Association to select a suitable place for its meeting without regard to any invitation which may be received. I do not believe in waiting for an invitation, but think it better for the Association to select some place where good hotel accommodations can be secured, and go there and pay their own bills. I will, therefore, make a motion that a committee of three be appointed by the chair to consider and report a place for holding the next annual meeting, and also a place for the fall meeting.

The motion was adopted, and the President appointed Messrs. Brackett, of Boston, Hall, of Quincy, and Parker, of Burlington, Vt., as the committee.

President Nevons then introduced Mr. Abbott, of New York City, formerly of South Bend, Ind., who gave some interesting incidents of his service as superintendent of water works at the latter place.

COURTESIES EXTENDED BY FALL RIVER FRIENDS.

Mr. Hawes. — The members of the Association are invited to visit our high-school building at the close of this afternoon's session. To those of you who have not seen it, I will say it is a very fine building, probably the finest school building in the United States, if not in the world. It is no fault of the city of Fall River that we had it, but a big and noble hearted woman gave us this institution as a monument to her departed son. It is fully equipped with apparatus for all kinds of study, — geographical, philosophical, chemical, mechanical, astronomical, and all other kinds of "icals," — and it is really worth your time to visit it. It is only a

short distance from here, and we can easily walk to it. In the hall in the upper part of the building is a marvellous picture which her son purchased in Germany, — Kaulbach's latest work, "The Era of the Reformation," costing him in this country over $35,000. To-morrow our city government invites you to take your breakfast early at your own expense, and then to take barges at our expense, and go to our pumping-station. We feel very proud of it, for it never looked so well before, and it may never look so well again, and we want you to see it now. After examining it, you will enter the barges and proceed to the wharf, where you will take a steamer and go down the bay for a fish dinner, with plenty of clams for all of you except the President, and a sail, returning in season for you to take the afternoon train to Boston.

On motion of Mr. Coggeshall, the invitation was accepted with thanks. The Convention then adjourned to afternoon.

AFTERNOON SESSION.

The convention reassembled at 2.30 P.M.

On motion of Mr. Brackett, the report of the Committee on Badges was taken from the table, and on motion of Mr. Darling, the badge recommended by the committee was adopted as the badge of the Association.

REPORT OF COMMITTEE ON LOCALITY OF NEXT CONVENTION.

Mr. Brackett. — The committee, after considering the question of a suitable place for holding the next annual convention, have concluded that either Burlington, Vt., or Portland, Me., would be desirable, and would suggest that a vote be taken by the Convention as to both of these places.

After some discussion, the members who desired to express their preferences voted as follows: For Burlington, 4; for Portland, 6; for Worcester, 10.

And on motion of Mr. Stearns it was voted that the next convention be held at Worcester.

Mr. Brackett. — The committee think it would be well to leave the selection of the place of the fall meeting to the Executive Committee, with the suggestion that if any members have any preferences, they will communicate them to that committee.

On motion of Mr. Stearns it was voted to accept the report of the committee, and adopt its recommendation.

Later in the afternoon session Mr. Coggeshall brought up the matter of the place for holding the next annual convention, and said: —

"It seems the vote which was taken early in the afternoon — which was not a very full vote — does not meet with the approbation of many of the members, who seem to think that Worcester is not exactly the place for us to meet. Now, I want to have a successful convention next year. I am willing to go anywhere; I am sure I shall have a good time, but I want to go to a place where we shall certainly have a full attendance. And in order that a place may be selected that will, perhaps, prove more satisfactory, I move that the vote that was passed whereby we decided to go to Worcester be reconsidered."

The motion was adopted unanimously.

The President. — I sincerely hope we will hold our meeting in Portland. It is a first-class place to go to. There is a large harbor there, and plenty of water. We are not obliged to ask permission from the city authorities. We have money enough to pay our bills, there are good hotels there, and lots of things to be seen, and we can have a first-class time. Worcester is a good place in which to hold political conventions, but I think Portland will suit us better for a water-works convention. It is a place easy of access; we can go on the cars, or those who prefer can go on the boat at night, and be there all ready for business the next day.

On motion of Mr. Fitz Gerald, the Convention voted to go to Portland.

Prof. W. T. Sedgwick, of the Massachusetts Institute of Technology, then read a paper entitled "Recent Progress in the Biological Analysis of Water." The paper was discussed by Messrs. Drown, Stearns, Fitz Gerald, Noyes, Allis, and Chase.

On motion of Mr. Brackett, the thanks of the Association were extended to Professor Denton, for the instructive and interesting lecture given by him on Wednesday evening.

Adjourned to 7.30 P.M.

EVENING SESSION.

At the opening of the evening session, the following-named gentlemen were elected members of the Association : —

ACTIVE.

Millard F. Wright, Superintendent, Lowell, Mass.
Ansel G. Hayes, Assistant Supt., Middleboro', Mass.
Benj. P. Hale, Water Registrar, Haverhill, Mass.
Edward T. E. Lansing, Little Falls, N. Y.

ASSOCIATE.

William Wolfendale, Agent, "Water-Works Supplies," Fall River, Mass.
John Hattersley, "Common-Sense Packing," Brooklyn, N. Y.
Charles H. Eglee, "Contractor," Flushing, N. Y.
N. F. Ryder, "Varnish Manufacturer," Middleboro,' Mass.
Portsmouth Wrench Co., Boston, Mass.

A letter was received from Desmond Fitz Gerald, declining to accept the office of Senior editor, and, on motion of Mr. Hall, the Executive Committee was given full power to act in filling the vacancy in the office of Senior editor.

HOW TO PREVENT MAINS FROM FILLING WITH SEDIMENT.

The President called up for discussion the topic, "Suggestions as to the best methods to prevent mains from filling with sediment," and invited Mr. Darling to address the Convention.

Mr. Darling. — I have had very little experience in this direction. My mains are very clear of sediment. The system we have in Pawtucket, of taking the sediment out of the water before it is sent into the pipes, accomplishes the purpose, and we do not get any bad results from sediment in any form or nature. I remember on one occasion a gentleman who lives on a dead end complained

to me that the pipe was all filled up with silt and sediment, and the water was terribly bad. I told him that to satisfy him we would go down and take the plug out at the end of the pipe, and show him whether he was correct or not. When the men had got it dug up and the plug knocked out, he saw there was no sediment there at all, which convinced him he was entirely wrong, and settled that question. I presume there may be people here who have trouble with sediment, but so far as I am concerned, I don't know anything about it.

Mr. Keating. — The difficulty in Halifax is with incrustation in the water-pipes, and not sediment. In other places, where there were small works, sediment has been liable to collect, and I suppose the usual method of removing it is the one I adopted, simply to put in blow-offs at suitable places and blow it out. Our method of removing the incrustation in pipes, and I suppose sediment can be removed in precisely the same way, is to put a scraper through. The scrapers are run by the power of the water in the pipe itself, and where they are properly constructed and handled they will take out everything in the pipe, unless it is lead which has run through and sticks too far into the pipe. If it projects far enough it may possibly stop the scraper, but, as matter of fact, I haven't found any difficulty except in one or two cases. If it doesn't project more than half an inch or three-quarters of an inch, the scrapers will pass. The longest distance I have so far operated one of these machines is five miles and a half, which I think is about long enough. We put in catch-boxes at intervals varying from half a mile to a mile, according to the configuration of the ground, but in practice I have found it was not necessary to have so many.

Mr. Hawes. — My friend, Mr. Jones, suggests the best way to prevent the mains from filling with sediment is to keep it out of the pipes. We had an alarm of fire yesterday morning, and towards noon, as I was riding along, a gentleman hailed me and wanted to know what kind of stuff we supplied through our water-pipes. I told him anything he wanted, — water, fish chowder, or anything else. [Laughter.] He brought out an iron bolt and a nipple, and said both of those came through the hydrant that morning. I told him there was no extra charge for them; he could have them, and welcome. [Laughter.] Now, if we had kept them out they wouldn't have been in the pipes; so I think my friend Jones' suggestion, that the best way to prevent the accumulation of sediment is to keep it out of the pipes, is a good one.

PUBLIC AND PRIVATE WATER-WORKS.

The next topic for discussion was, "Should the public and public corporations be chiefly responsible for the sins of private corporations, and which, all things considered, is most conducive to public interests: Water-supply furnished by municipalities or by private corporations?"

The President called on Mr. Hall, of Quincy.

Mr. Hall. — I have but very little to say. In answer to the first part of the question, speaking from the standpoint of a manager of a private corporation, I should say, with my present experience, that if private corporations commit any sin the public is responsible for it. To commence with, private water companies are usually given a charter by the Legislature, granted because certain inducements are held out by representatives of the community desiring a water-supply.

Feeling unable to take hold of it, or unwilling to take hold of the matter themselves as a town or a community, these inducements are offered to parties to make an investment for the sake of an investment, with a view of obtaining a return, of course. Among other things, it is customary for a town or a city to agree to take a certain number of hydrants at a stipulated price. That is so much income assured to commence with. Every water-works engineer well knows the difference in the cost between furnishing a supply for domestic purposes alone, and furnishing a supply sufficient for fire protection. Consequently, from the inducements that are offered to the projectors, a larger plant is established, larger mains are laid, making an extra cost for the works.

When it comes to the case in hand, numerous difficulties are encountered. In the first place, it is a private corporation, and they are never doing their work in a satisfactory manner to all the public; although I claim that the work done by private corporations, as a rule, is done by men who put their money into the works for an investment, and it is as much for their interest to do good work as it is for a city to put in good works which are to be controlled by the city. When the works are built many people suppose that the hydrants are for them to use just as they see fit; firemen are to play with them whenever they feel inclined; if a man wants to water his garden he thinks he has a perfect right to go and open a fire hydrant and connect the garden hose with it; or if he wants to do a little plastering he thinks he can open the hydrant to get water to mix the mortar with; or if there has been no rain for a few days he thinks he can go and get a few tubs of water to do washing with. But when he finds out that the hydrants are for no such purpose, then there is music in the air. The result is, this increased cost of the investment has not yielded the returns which were anticipated, which the company had reason to expect, and the question of future extensions comes up, and it gets to be a question with the corporation, perhaps, whether they shall run pipes of sufficient size to furnish fire protection, or whether they shall run pipes for domestic purposes alone. Taking all things together, in many cases the supply that is furnished, I think, looking wholly from the financial standpoint, is furnished cheaper to the community, especially to a small community, — I don't know how it would be with a large community, — by a private corporation than it would be by works under public control. That is all I think of to say now. I shall be glad to hear from some one else before I attempt to say anything more.

Mr. Hawes. — "Should the public and public corporations be chiefly responsible for the sins of private corporations, and which, all things considered, is most conducive to public interests: Water-supply furnished by municipalities or by private corporations?" I have had this paper about three weeks, and I haven't got that question clean through my head yet. [Laughter.] If any of you can understand it, I should like an explanation before I start. "Should the public and public corporations be chiefly responsible for the sins of private corporations?" No. Every tub must stand on its own bottom. [Laughter.] This very strongly hints that your private corporations are tremendous sinners, and you want to shift the responsibility of that sin on to the public. That is what I should judge by the way it reads. Now, that can't be done. Any man who sins must take the consequence of it. A public corporation and the public may be the sufferers from the sins of private corporations, but they cannot be responsible for your sins. You hardly ever saw a man who had committed a sin who didn't

want to lay it on to somebody else when he was found out. You never saw a man who was driving a nail strike his finger but what he would blame the man who was next to him, or if there wasn't anybody there he would blame it on the hammer. [Laughter.] It wasn't his fault, of course! We are all perfect, we start that way, and we think we can't be anything less. Now, I say that it is my opinion that the public and public corporations should not be responsible for the sins of private corporations; and I am sorry that the man who wrote that question should think it necessary to accuse the private corporations of being such sinners.

"And which, all things considered, is most conducive to public interests: Water-supply furnished by municipalities or by private corporations?" I say, in my opinion, emphatically, water-supply furnished by municipalities. Now, while our friend, Mr. Hall, tells us it is the object of private corporations to have everything all right, still there is a selfishness prevalent in all our natures, a desire to make money out of private speculations. Water-supplies owned by private corporations are generally private speculations, and although they may want everything right, they are very apt to buy about the cheapest pipe they can buy to make them right, and about the cheapest material in every way to make them right. And they may be all right enough to start off with, but they are not generally supposed to be; they don't have the reputation of being of a character that lasts and wears well. But when the water is supplied by municipalities it is generally supplied through water commissioners, or through some committee who feel that they have a right to spend the public money a little more liberally than they would their own, and therefore they are likely to lay out a better plant on the start, and to see that it is kept up in better shape to the finish, in my opinion, than private corporations will do. Therefore I should say it was better for municipalities than for private corporations to furnish water. That will open the subject, gentlemen; now pitch into it. [Laughter.]

Mr. Codd. — I think one advantage of public works over private works is, that the town is likely to have extensions into the outlying districts made sooner if the town or city owns the works than if a private company owns them.

Mr. Keating. — I know one or two places where water works have been put in by private corporations which have not proved altogether a success. In my opinion it is most decidedly to the interest of the public that the municipalities should own their own works. If they do not build them, and they are built by a private company, the probabilities are they will have to buy them out at some time or other. And many of the companies that put in works, start with that idea, that the corporation will ultimately have to buy them out. That was the case in Halifax. The works there were first put in by a private company. They were designed on altogether too limited a scale, and the pipes that are now left of the original company's works I am taking out as fast as I can, for they are all too small. The entire works have been enlarged throughout. I know of another town in Nova Scotia, the town of Yarmouth, which is at present supplied by a private company. There was some hitch between the company and the town, and as a result the town haven't the right to use the hydrants at all, even in case of a fire. They have opened wells, and they have three of our fire-engines, and are obliged to depend upon them for fire protection. Of course

we all know that when a private company puts works into a place they do it for the purpose of making money out of it, and if they can't see a chance to make something they won't go into it. The people have to pay more, the rates will probably be higher for the water, and in all probability in a few years the corporation will be forced to buy the works out.

Mr. Hall. — I think Mr. Darling can give us some ideas on this subject.

Mr. Darling. — I am like the good old deacon who was always ready to add his testimony whenever called upon. I am perhaps situated a little differently from most of the members. While our city owns the works, we supply three towns with water, so that, practically, we act as a private corporation. Our works were built by the city, and the outside works were also built by the city, and I will say that we endeavored to build as good works outside of the city limits in the adjoining towns as we did in our own town. The same rules and regulations that apply to our own people apply to those outside. We sell outsiders water on the same basis that we sell it at home, and we claim to sell water as low as any works in the United States similarly situated. We sell as low as six cents per one thousand gallons, and we pump against two hundred and sixty-eight feet head. Of course we don't claim to come alongside of a gravity works. Our outside customers fully appreciate what we do for them, and are perfectly satisfied, and I haven't any doubt that my friend Mr. Hawes' customers are perfectly satisfied with him. As a rule, I should agree with what he has said on the subject; but being situated as we are, and going outside to supply the adjoining places, we have thought it proper to do it.

Mr. Holden. — I don't know, Mr. President, as I have anything particular to say with regard to this matter. I have been with a public company, and I am now with a private company, and I don't know but what both of the works have always been satisfactory to the consumers. I have had very little fault found in either place. I don't know that we have committed any sins on our works that the public are responsible for or complain about. At any rate, everybody has seemed satisfied to come in once a quarter and pay the water bills, and I certainly never have had any more trouble on private works than I have had on public works in that respect. Talking with our treasurer a little while ago, I asked him how much he ever had in bad bills. He told me he had been treasurer of the company for fourteen years, and there were less than forty dollars of bad bills outstanding.

Mr. Babcock. — It seems to me the key to this whole question is the rate of interest and the value of money. Municipal corporations have the advantage in that respect over private companies. There isn't a municipal corporation in the State of New York but what can borrow money at three per cent., and no private company can afford to put water works in that will produce less than six per cent. In one case the only revenue necessary to be derived is a revenue sufficient to pay the three per cent. and to provide for a sinking-fund; in the other case it must be at least six per cent. It seems to me that is the key to the whole situation in favor of municipal corporations.

Mr. Frost. — May I be allowed to say a word on this subject, for I am personally interested in this question, and I wish the discussion might be continued to some definite conclusion. I live, and own some property, in the town of Plainfield, N.J., which is just now agitated with the subject of water works. It

is the largest city east of the Alleghanies which is unprovided with water works, and for some years they have been trying to introduce them. The city contains a population of about 12,000, and it is entirely free from debt. The old New Jersey element in the population is strong enough to prevent any vote by the — I will call them New Yorkers, because the bulk of the business men who live there do business in New York, and come home at night, and they are all in favor of water works — the old resident population is strong enough to prevent any bonding of the city. The subject is just now under consideration by the council. There are a good many people who wish to take a franchise, and the question I wish to submit to the practical men here is this, as Mr. Babcock has just put it: The city is entirely free from debt, and they can borrow all the money they like at four per cent. It is estimated that the works will cost about $200,000, and they want to couple sewerage with the water, the whole to cost about $400,000. They haven't discovered any method yet by which they can give a franchise for sewerage, and really I would like to know if any gentleman here knows of any method by which it can be done. The only town I know of where it has been done is Shreveport, La. Samuel R. Bullock built the water works there, and they have a system of sewerage under franchises in connection with the water works. There are more water works run by the cities and towns in New England than in any other part of the United States. I believe Michigan runs altogether to private companies, and Wisconsin practically so. Now, what would the majority here say was the proper thing to do in Plainfield, — borrow the money at four per cent. and bond the city and build the water works, or give a franchise? That brings the matter right down to something practical. The population is not a manufacturing corporation, and there are no large establishments there which will desire to take the water. Most of the private houses are built on large lots, and the people do business in New York. Water would have to be supplied for fire purposes, but the franchise men have not seen any great revenue to be derived from the works, although they seem very anxious to get a franchise, and they say that in three or four years they think they will be able to get a return. This is a very interesting question to me, because I am personally interested in it, and wish the gentlemen here would bring it right home to themselves and say what they would do if they were in the council and had to decide whether it would be best to bond the city, or whether it would be best to give franchises, and let others take the risk. One of the gentlemen has spoken about the increased cost of materials, pipes, etc., for a fire-supply. Does any water company go to any extra expense to furnish fire protection? I believe the amount of water used in the city of New York for fire purposes is only about 6,000,000 gallons a year.

Mr. Darling. — The gentleman must understand that you have to go to the expense of the hydrant service, whether you use the water or not. It is on the same principle that you insure your house. You insure it, and it doesn't burn down; you don't want it to burn down, but still you keep paying the insurance. It is on the same principle that the hydrants are furnished, and you have to go to the expense of putting them in. The water is of small moment.

Mr. Frost. — I did not consider it in that way, but only with regard to the size of the pipes. Of course I can see it costs as much for the hydrants whether you have fires or not.

Mr. Darling. — As to the size of the pipes in any well-organized water works, I claim that to have good water works the first thing you want to do is to prove that you have good fire protection. If you satisfy the public whom you are supplying with water that you can put the water over any building in the town, they will have confidence in the water works at once; and I think that is one of the first and most important things to be considered.

Now, as far as the consumption is concerned, I maintain, as I did at the convention at Louisville, where I read a little article on that subject, that no private corporation would go into any town or city if it was to be entirely dependent upon the family supply, for it could not get enough out of it to make the works a paying institution. I have in my works, as I have said before, four divisions outside of Pawtucket — the East Providence, Central Falls, the Lonsdale and Valley Falls, and the Berkeley and Ashland division. There are large manufacturing interests there, and that is what induced us to go into those sections. I will say this, that if you have got a city of 35,000 inhabitants, with a fair supply of corporations, or a prospect of a good supply of corporations, the city could better afford to put in works than to let any one else in; but if you have got a city that is not so situated, it would be far better for you to let some private corporation in, if you can get them to come in, although I have my doubts of their coming in under the circumstances, unless you will agree to pay a hydrant rental far above what would naturally be expected. What I consider as a fair price, under favorable circumstances, is anywhere from $30 to $35. I contend you cannot afford to put in the extra pipes and the hydrants for much less than that price. The actual cost of the maintenance of them will be about that amount, even if you use but a little water, or, in fact, if you use none. That is the result of my experience as to whether I would have a private corporation come in or whether I would advise the city or town to build the works.

Mr. Wilder. — I would state that I represent a small private works, and that when we started we first thought of putting in merely a domestic service, and estimates were made upon that basis, and estimates were also made as to the cost of a fire-service connected with it. We found that the cost would be nearly double. We made a proposition to the town, which was accepted, to furnish the hydrants and put in the extra service, which would involve an increase in the size of the pipes, and also of the capacity of the reservoir, and base the price of the hydrant-rental to the town at four per cent., which is $26 a hydrant. The people in the village feel perfectly satisfied, and I have no doubt they will be glad to renew the contract when it expires.

Mr. Conant. — As I understand the gentleman he cannot get a vote of the town to build the works, so they will either have to go without works or let a private company in. I have charge of a private company in a town which was in about the same fix. One village in the town wanted to put in works and the other village didn't, and they couldn't get a vote of the town to do it. So a contractor went there, made his contract with the town, and we now furnish them with hydrant and domestic supply. I don't know that there is any great fault found with us, and I am not aware that we sin very much; if we do, we are willing to be forgiven. Of course we want to make something out of it, if we can, and it is true, as has been said by one of the gentlemen, that while public corporations do not expect to more than pay the interest on the cost and to provide

for the sinking-fund, private corporations want to make a profit over and above the cost.

Mr. Morse. — I want to say just a word. I represent a private water company in Haverhill, and we don't charge the city anything for water for fire purposes, yet we make a living all the time. As to liberality in laying pipes, I will state we put them anywhere where they will pay five per cent. on the cost, throwing in the water to the city. We don't charge a cent for fire purposes, and the city puts in its own hydrants.

Mr. Fales. — I will relate a little experience which I have had in the town of Tonawanda, which is one of the largest lumber ports in the world. The population is about equally divided as to nationalities, and when the question of putting in water works came up the situation was very much as the gentleman describes it to be in Plainfield, the voters being about equally divided in opinion. The matter was further complicated by the introduction of the question of sewerage. The drainage of the town was poorly provided for, and many people thought a system of sewerage should be introduced before a water-supply was put in. Finally a private company offered to make a contract with the town. The town is situated partially in Erie and partially in Niagara counties, with a population of about 6,000 in each village. The north side is, perhaps, a little more genteel than the other part of the town. We went to work first on the north side, and made a contract to put in six miles of main there. We agreed to furnish a perfect fire protection, and we allowed the members of the common council the right to say what size of main should be put in, and after settling that we were to put in as many fire hydrants on the six miles of main as the common council required. They thought ninety-seven would be enough; so we put in ninety-seven hydrants, and the contract was that after that we should receive for each additional hydrant $40 a year. We were to lay four hundred feet of pipe, and on every four hundred feet of pipe receive $40. After a time the south side accepted the proposition of the company, and they have eight miles of main. The contract was, they were to have as many hydrants as they saw fit; and we placed on that eight miles of main one hundred hydrants, and on each additional four hundred feet we were to put another hydrant and receive $40 a year. Our contract specifies that at any time when they think the works are not in shape to give perfect fire protection, we shall furnish them twelve hydrant streams at a perpendicular height of eighty feet. We have been called on twice to do it, and have performed the test to the satisfaction of the city authorities. We try to make the rate to consumers as low as it is in any town similarly situated, and so far no fault has been found. I think $40 is as cheap as any company can afford to maintain hydrants.

Mr. Conant. — Do you pump the water or have gravity pressure?

Mr. Fales. — The contract with the town is for twenty years, or they can buy at any time they see fit. The water is pumped. The pressure is an even pressure of 40 pounds at all times, and the fire pressure is from 80 pounds to 120, and we carried it at one time to 135 pounds. The mains are Wyckoff wooden pipe, and we have never had a break at that pressure.

Mr. Hall. — I think the remarks of the members here to-night have demonstrated this: That many small communities are at present supplied with water by private corporations that otherwise would be entirely without any system of

water-supply, and would remain so for a long while if they had to wait for the supply to be put in by the town or the city itself. That seems to be the result of the experience of every one who has spoken as representing private works. That is the situation in the place I represent; and in several places that I have in mind, places that I have had occasion to visit within a comparatively short time, where they are agitating the question of a water-supply, there is decided opposition to the town taking hold and building the works. They couldn't get the town to vote to do it, but they have voted to contract with private companies to build works for them. I think private companies are doing a great deal of good, and many communities are receiving the benefit of a public water-supply which, without these private companies, would be without an adequate supply of water for domestic purposes, or for the purpose of fire protection.

Mr. Noyes. — This discussion has consumed considerable time; but I would ask the convention to excuse me if I say a word with particular reference to Mr. Frost's question as to the matter of selling a franchise for the purpose of providing a system of sewers for a place. I believe there are two places in New Jersey where they have a system of sewers with a regular fee for entrance and annual rentals, on the same principle as in the case of a water-supply. Then, as to his question as to whether Plainfield should be supplied by a private company or by the municipality itself, I think Mr. Babcock answered it in a nutshell, with this exception in favor of private works, that in the management of them politics can be kept out. That seems to me to be one objection, possibly, to municipal management; but if public works can be managed with the same sagacity and prudence as private works, the municipality should by all means own the works. Ordinarily a private company is organized to put in water works as a matter of business; and a contract with the town for hydrant rentals is practically equal to a good interest on the cost of the works. Many companies that are organized and works that are built to-day are on that very basis, and their bonds are sold on the market because the hydrant rental is equal to the interest on the bonds, and the works are generally bonded very closely to the full cost. The works are generally put in, — I do not say they all are, because there are many private works honestly constructed, — they are generally put in for the five or ten years during which it is supposed they will be run by the private company; and then the contractors, or the parties in interest, will work the politics of the town so as to sell the works at from thirty-three to fifty per cent. more than it would cost the town to have built them originally. The price of the works is made up not so much on the basis of the actual intrinsic value as on the income they represent. I have in mind one municipality that will soon be called upon to buy private works, and it will have to pay out inside of three years from thirty-three to fifty per cent. more than the works cost, and will have to rebuild two-thirds of the works.

CLOSING EXERCISES.

Mr. Noyes. — If not out of order, I should like to say one or two words with reference to our meetings during the past year. It has given me great pleasure to attend those meetings, and I think I voice the sentiment of every member who has had the privilege of attending them, in saying that they have been very interesting and profitable to us. This has been due largely, while, of course, in

some part to the exertions of the members, and the interest they have taken, to the earnest work and harmonious action of our officers, and especially to our President and our Secretary. And although it is out of order, as a general thing, to move a vote of thanks to two men who do their duty (and it is the duty of a man who takes an office to do all he can to enhance the interests of the association in which he takes that office), yet I do believe it is a proper thing for me at this time to move that a vote of thanks be extended to the President for the work that he has so earnestly undertaken, and has so successfully carried out during the past year. [Applause.]

Mr. Darling. — Mr. President, I rise to second the motion. It was my fortune last year to hold the position to which the gentleman was elected at Providence. Owing to circumstances beyond his control he was not able to stay through the sessions of the Convention at that time and take the chair, as it had been customary for the newly-elected president to do. I, therefore, promised him that I would in his behalf accept the position for him, and make his inaugural address. That I did, agreeing at that time, as his representative, to perform the duties of the position during the year to the best of his ability, and for the best interests of the Association. It gives me great pleasure to say that he has confirmed what I said for him at that time, and that he has performed the duties of his office to the satisfaction, as I believe, of every member present. I take great pride in seconding the resolution.

The motion was put by the Secretary and adopted.

The President. — Gentlemen of the New England Water Works Association: I thank you heartily for this expression of your kind feeling towards me; but I think you have gone a little too far. I do not think the President would have amounted to much unless he had had such a man as this [pointing to Secretary Coggeshall] alongside of him, and working with him. [Applause.] And I would also recognize the earnest spirit of coöperation that has been shown by the associate officers and every member of this Association. I said in my opening address yesterday that I should never forget the honor that you conferred on me when you elected me your President, and I am still of that opinion, only a good deal more so. I am sure that every one of you has shown me the greatest courtesy, and a spirit of willingness to overlook all the deficiencies that I have exhibited in this position.

As most of you know, I attended the Convention at Louisville, Kentucky, and while there I was the guest at the banquet, and was called on to speak for New England and the New England Water Works Association. I told them it was a pretty big subject, for while I was there I had learned that New England was bigger than all the rest of the United States, — in this respect, at least, that the membership of the New England Water Works Association outnumbered the membership of the national association by thirty. Our members to-day number 306, and, as I said in my opening remarks, when our membership roll is called, we have an answer from the Provinces, from the land of the thistle and the heather across the water, and from all sections of this country. We have an institution that we should be proud of, and I do want to see it keep on and march steadily forward. I believe we are recognized now as a live institution. It is with a great deal of pleasure I resign my official position to the man you have selected to be my successor, for he is thoroughly in earnest in this work that we

are engaged in, and I know he will devote himself to the interests of the Association. [Applause.]

Mr. Noyes. — I want to be permitted now, Mr. President, to complete my motion, which, preferring not to put it myself, I made only in part. I move the thanks of this Association be extended to our worthy Secretary for his faithful and efficient work. [Applause.]

The motion was adopted.

Mr. Coggeshall. — Gentlemen, without making any remarks I will simply thank you for your expression of appreciation.

Mr. Hawes. — I want to call the attention of members to the blue prints. We went into this some years ago, and we carried it out for two years with very good success, and I hope we will not give it up. I think it is one of the best things we have, and I do wish that next year members will take a little more interest in it than they have this year.

Adjourned.

Friday, June 14.

EXCURSION TO NEWPORT.

This, the closing day of the Convention, was devoted to excursions and sightseeing as guests of the city of Fall River. Under the guidance of Commissioner Hawes, Superintendent Kieran, and Registrar Robertson, the Association early in the forenoon took barges and inspected the water works and many other features of interest about the city. At eleven o'clock the party, augumented by many guests from Fall River and other places, boarded the steamer "Mt. Hope," specially chartered for their use, and steamed down the river; at Bullock's Point a landing was made for dinner, at the conclusion of which remarks appropriate to the occasion were made by Mayor Jackson and others, and ex-President Nevons and President Brackett extended to their hosts the heartiest thanks of the Association for the bountiful hospitality that had been extended to it during the three days of the Convention. Again boarding the steamer, the party sailed down to Newport, where an opportunity was afforded for an inspection of the new steamer "Puritan." Leaving Newport, the magnificent sail of the morning was retraced to Fall River, which was reached in time for the members to take the evening trains for their homes.

A very pleasant feature of the Convention was the musical contributions of Messrs. Pratt, Monroe, and Milligan, who not only sang from time to time during the sessions of the Association, but also gave very enjoyable concerts in the parlors of the hotel each evening, after the meetings were adjourned.

LIST OF BLUE PRINTS DISTRIBUTED AT THE CONVENTION.

1. Contractors Plant, Howland, & Ellis, Boston, Mass. G. E. Wilde, Supt., J. Frank Williams, C. E.
2. Derrick for Pipe Laying, R. C. P. Coggeshall, New Bedford, Mass.
3. Weymouth Water Works, C. J. Ries, East Weymouth, Mass.
4. Sample Page of Section Book, Norwich Water Works, C. E. Chandler.
5. Design for 6-in. Two Outlet Fire Hydrant. Capt. J. L. Lusk, U. S. A.
6. Chimney at Pumping Station, Pawtucket, R. I. Wm. B. Sherman.
7. Dam and Pumping Station, Pawtucket, R. I. Edwin Darling.

8. Method of Taking and Storing Water at Middleboro' Water Works, Joseph E. Beals.

9. Flexible Joint and Screen for Suction Pipe, Geo. A. Stacy, Marlboro', Mass.

10. Distribution System, Little Falls, N. H. Stephen E. Babcock.

11. Specimen Page of Service Book, Woodstock, Vermont. Frederick W. Wilder.

LIST OF EXHIBITS BY ASSOCIATE MEMBERS AT THE CONVENTION.

1. Hersey Meter Co., Boston, Mass., Water Meters.
2. Chapman Valve Mfg. Co., Boston, Mass., Hydrants, Gates, and Valves.
3. Walworth Mfg. Co., Boston, Mass., Water Faucets, Plumbers' Tools, and Hall Tapping Machine.
4. Ross Valve Co., Troy, N. Y., Fluid Pressure Regulator and apparatus for regulating steam-car heating.
5. Geo. E. Winslow, Waltham, Mass., Reservoir Indicator and Recorder.
6. R. D. Wood & Co., Philadelphia, Pa., Photos. of Hydrants and Valves.
7. Tuerk Hydraulic Power Co., N. Y., Water Motors.
8. Bnilders' Iron Foundry, Providence, R. I., Globe specials.
9. Union Water Meter Co., Worcester, Mass., Rotary and Piston Meters.
10. Whittier Machine Co., Boston, Mass., Samples of Service-pipe.
11. Waste Water Prevention Co., N. Y., Thomson Water Meters.
12. Portsmouth Wrench Co., Boston, Mass., Hub Shaking Grate.
13. Locke Steam Damper Co., Salem, Mass., Steam Damper.
14. Common Sense Metallic Packing Co., Brooklyn, N. Y., Packing.
15. Galvin Brass and Iron Works, Detroit, Mich., Hydrants and Valves.
16. American Frost Meter Co., Boston, Mass., Meters.
17. H. R. Worthington, N. Y., Photos. of Pumping Engines.
18. Asbestos Packing Co., Boston, Mass,, Packing.
19. Peet Valve Co., Boston, Mass., Valves.

REGISTER OF THOSE IN ATTENDANCE

AT THE

FALL RIVER CONVENTION, JUNE 12, 13, 14, 1889.

ACTIVE MEMBERS.

Solon M. Allis, Superintendent Water Works, Malden, Mass.
Stephen E. Babcock, Hydraulic Engineer, Little Falls, N. Y.
George E. Batchelder, Water Registrar, Worcester, Mass.
Charles H. Baldwin, Boston, Mass.
Joseph E. Beals, Clerk and Water Registrar, Middleboro', Mass.
Emmett C. Bennett, Superintendent and Secretary Water Works, Ticonderoga, N. Y.

Charles E. Bolling, Superintendent Water Works, Richmond, Va.
Dexter Brackett, Superintendent Eastern Division Boston Water Works, Boston, Mass.
George F. Chase, Superintendent Water Works, Taunton, Mass.
Jonas M. Clark, Superintendent Water Works, Northampton, Mass.
William F. Codd, Superintendent Water Works, Nantucket, Mass.
H. W. Conant, Superintendent Water Works, Gardner, Mass.
R. C. P. Coggeshall, Superintendent Water Works, New Bedford, Mass.
Byron I. Cook, Superintendent Water Works, Woonsocket, R. I.
F. H. Crandall, Superintendent Water Works, Burlington, Vt.
Lucas Cushing, Assistant Superintendent Water Works, Boston, Mass.
Edwin Darling, Superintendent Water Works, Pawtucket, R. I.
Nathaniel Dennett, Superintendent Water Works, Somerville, Mass.
Thomas M. Drown, Professor of Chemistry, Massachusetts Institute of Technology, Boston, Mass.
Horace L. Eaton, City Engineer, Somerville, Mass.
H. M. Fales, Superintendent Water Works, Tonawanda, N. Y.
G. B. Fitts, Superintendent and Water Registrar, Attleboro', Mass.
F. F. Forbes, Superintendent Water Works, Brookline, Mass.
Albert S. Glover, Water Registrar, Newton, Mass.
Robert M. Gow, Superintendent Water Works, Medford, Mass.
Frank E. Hall, Superintendent Water Works, Quincy, Mass.
Joseph C. Hancock, Superintendent Water Works, Springfield, Mass.
James H. Hathaway, Water Registrar, New Bedford, Mass.
William M. Hawes, Water Commissioner, Fall River, Mass.
Ansel G. Hayes, Assistant Superintendent Water Works, Middleboro', Mass.
Horace G. Holden, Superintendent Water Works, Nashua, N. H.
Horatio N. Hyde, Jr., Superintendent Water Works, Newtonville, Mass.
A. W. Inman, Wisconsin Construction Co., Boston, Mass.
David B. Kempton, Water Commissioner, New Bedford, Mass.
Patrick Kieran, Superintendent Water Works, Fall River, Mass.
George A. Kimball, Civil Engineer, Boston, Mass.
E. H. Keating, Engineer and Manager Water Works, Halifax, N. S., Canada.
Edw. T. E. Lansing, Civil Engineer, Little Falls, N. Y.
W. F. Learned, Civil Engineer, Watertown, Mass.
Augustus W. Locke, Civil Engineer, North Adams, Mass.
Joseph A. Lockwood, Superintendent Water Works, Yonkers, N. Y.
James L. Lusk, Captain Corps of Engineers, U. S. A., Washington, D. C.
A. E. Martin, Superintendent Water Works, South Framingham, Mass.
Charles W. Morse, Superintendent Water Works, Haverhill, Mass.
James W. Morse, Superintendent Water Works, Natick, Mass.
H. H. Lowe, Superintendent Water Works, Clinton, Mass.
William E. Nason, Superintendent Water Works, Franklin, Mass.
Hiram Nevons, Superintendent Water Works, Cambridge, Mass.
Albert F. Noyes, City Engineer, West Newton, Mass.
Weaver Osborne, Water Commissioner, Fall River, Mass.
F. H. Parker, Burlington, Vt.
A. G. Pease, Superintendent Water Works, Spencer, Mass.

John F. Philbin, Water Registrar, Clinton, Mass.
John F. Plunkett, Water Registrar, Marlboro', Mass.
George J. Ries, Superintendent Water Works, East Weymouth, Mass.
Walter H. Richards, Superintendent Water Works, New London, Conn.
J. W. Ringrose, Secretary Water Works, New Britain, Conn.
W. W. Robertson, Water Registrar, Fall River, Mass.
Henry W. Rogers, Superintendent Water Works, Salem, Mass.
G. A. Roullier, Superintendent Water Works, Flushing, N. Y.
A. H. Salisbury, Superintendent Water Works, Lawrence, Mass.
William B. Sherman, Mechanical Engineer, Providence, R. I.
George A. Stacy, Superintendent Water Works, Marlboro', Mass.
Frederick P. Stearns, Chief Engineer State Board Health, Boston, Mass.
George F. Swain, Professor of Civil Engineering, Massachusetts Institute of Technology, Boston, Mass.
Charles H. Swan, Civil Engineer, Boston, Mass.
Charles K. Walker, Superintendent Water Works, Manchester, N. H.
Joseph Watters, Water Commissioner, Fall River, Mass.
Frederick W. Wilder, Treasurer Aqueduct Co., Woodstock, Vt.
Horace B. Winship, Civil Engineer, Norwich, Conn.
George E. Winslow, Superintendent Water Works, Waltham, Mass.
Millard F. Wright, Superintendent Water Works, Lowell, Mass.
Richard R. Yates, Superintendent Water Works, Northboro', Mass.

HONORARY MEMBERS.

George H. Frost, Engineering News, New York City.
E. R. Jones, Boston, Mass.

ASSOCIATE MEMBERS.

E. L. Abbott, Water Waste Prevention Co., New York City.
Chas. F. Angell, Builders' Iron Foundry, Providence, R. I.
Randolph Brandt, Selden Patent Packing, New York City.
A. H. Brodrick, Chadwick Lead Works, Boston, Mass.
Albert A. Blossom, Whittier Machine Co., Boston, Mass.
J. M. Betton, Henry R. Worthington, Boston, Mass.
G. H. Carr, Union Water Meter Co., Worcester, Mass.
Jarvis B. Edson, Recording Gauges, New York City.
J. H. Eustis, Walworth M'f'g Co., Boston, Mass.
Chas. H. Eglee, Contractor, Flushing, N. Y.
Jason Giles, Chapman Valve M'f'g Co., Indian Orchard, Mass.
H. A. Gorham, Gilchrist & Gorham, Boston, Mass.
Jesse Garrett, R. D. Wood & Co., Philadelphia, Pa.
F. W. Hood, Superintendent American Frost Meter Co., Boston, Mass.
John Hattersley, Common Sense Metallic Packing Co., Brooklyn, N. Y.
John C. Kelley, National Meter Co., New York City.
Charles Lynch, Galvin Brass and Iron Co., Detroit, Mich.
L. C. Lamphear, N. E. Agent Davidson Steam Pump Co., Boston, Mass.
L. McHugh, Galvin Brass and Iron Co., Detroit, Mich.

W. H. Moulton, Union Water Meter Co., Worcester, Mass.
W. H. Marsh, Tuerk Motor Co., New York City.
G. A. Polsey, Sumner & Goodwin, Boston, Mass.
L. A. Palmer, Portsmouth Wrench Co., Boston, Mass.
N. F. Ryder, Varnish, Middleboro', Mass.
Edward L. Ross, Chapman Valve M'f'g Co., Indian Orchard, Mass.
William Ross, Ross Valve Co., Troy, N. Y.
L. W. Sumner, Sumner & Goodwin, Boston, Mass.
R. J. Thomas, Agent Hegeman & Oliphant Water Filter Co., Lowell, Mass.
A. W. Worthley, Manager American Frost Meter Co., Boston, Mass.
George Woodcock, Nathaniel C. Locke, Salem, Mass.
H. D. Winton, Assistant Superintendent Hersey Meter Co., So. Boston, Mass.
W. Webster, George Woodman & Co., Boston, Mass.
John H. Wells, Vacuum Oil Co., Boston, Mass.

GUESTS.

J. P. Bacon, Stenographer of Association, Boston, Mass.
Thomas Burke, Engineer Fire Department, Marlboro', Mass.
J. E. Denton, Stevens' Institute, Hoboken, N. J.
W. D. Doyle, Tax Collector, Marlboro', Mass.
H. A. Fish, Malden, Mass.
Geo. L. Gould, Malden, Mass.
X. H. Goodnough, State Board Health, Boston, Mass.
Fred B. Gleason, Marlboro', Mass.
John Hall, Water Commissioner, Lowell, Mass.
C. W. Kingsley, Cambridge, Mass.
G. Frank Monroe, Boston, Mass.
Willis J. Milligan, Boston, Mass.
James T. Murphy, Commissioner, Marlboro', Mass.
P. B. Murphy, Town Clerk, Marlboro', Mass.
Francis L. Pratt, Cambridge, Mass.
F. A. Peckham, Engineering News, New York City.
F. W. Sheppard, Fire and Water, New York City.
F. E. Stevens, Boston, Mass.
H. Q. Sanderson, Chairman Water Board, Springfield, Mass.
E. A. Stevens, Malden, Mass.
Wm. T. Sedgwick, Professor, Institute of Technology, Boston, Mass.
Frank W. Skinner, Engineering and Building Record, New York City.
Wm. P. Walpole, Fall River, Mass.
A. S. Welch, President Water Board, Lowell, Mass.
Mayor Jackson, Fall River, Mass.
Mayor Newhall, Lynn, Mass.
Mayor Hall, Taunton, Mass.
Mayor Clifford, New Bedford, Mass.
Mayor Wiggin, Malden, Mass.
Ex-Alderman Haughwout, Fall River, Mass.
Chief Engineer Davoll, Fall River, Mass.

City Messenger Crosson, Fall River, Mass.
Ex-Mayor Milton Reed, Fall River, Mass.
Judge Blaisdell, Fall River, Mass.
Ex-Congressman Davis, Fall River, Mass.
Frank Steavens, Fall River, Mass.
City Clerk Pike, Cambridge, Mass.
Alderman F. H. Teele, Cambridge, Mass.
President Common Council Bingham, Cambridge, Mass.
Mr. Howland, Cambridge, Mass.
State Senator Howard, Fall River, Mass.
William F. Harbach, Newton, Mass.
Edmund T. Wiswell, Newton, Mass.
City Clerk Leonard, New Bedford, Mass.
City Auditor Topham, New Bedford, Mass.
President Common Council Tucker, New Bedford, Mass.
Chief Engineer Macy, New Bedford, Mass.
Edmund Wood, New Bedford, Mass.

PAPERS READ AND DISCUSSED AT THE CONVENTION.

HYDRANTS.

BY

George A. Stacy, Superintendent of Water Works, Marlboro', Mass.

Mr. President and Gentlemen : — In presenting this paper I do not expect to give you anything new or startling, but to give you a few ideas on hydrants, gained by a short experience in the management of Water Works in a country town; and if in the reading of this paper and its discussion, any facts are brought out that will be of value to any one, the ambition of the writer will be satisfied.

Knowing from experience that circumstances alter cases, this paper should be considered from a Marlboro' standpoint (as our friend Mr. Kingsley would say), a town of from twelve to thirteen thousand inhabitants, built upon hills and valleys; and the sub-soil being mostly of hard clay, a little gravel and quicksand, and an abundance of rock all over the town of about every kind and quality known to this section.

Our works were constructed on a liberal scale in regard to size of pipes, number of gates and hydrants. It has been my experience that for four or five months in the year the hydrants give me more care and anxiety than any other part of the works. These iron posts, standing like sentinels in our streets, seem of less importance than a hitching-post; but the fire-alarm sounds, the anxious citizen counts the box, and as the apparatus of the fire department comes rushing into position in a moment, this apparently useless and neglected post becomes a thing of great importance and interest, for it stands, perhaps, if it is in proper condition, between him and great financial loss or ruin.

Looked at in this light they are worth all the care and trouble it takes to keep them in proper order. As it is the unexpected that often happens, no hydrant on the works can be neglected; all must receive the same care and attention. For the fire-fiend, like other evils, seems to delight to attack us in our weakest spot, where we are least prepared to give him battle.

I find that there is considerable difference in the way hydrants are cared for on different works, and in the way and time inspections are made. I have made it a rule to thoroughly inspect them in the spring and fall.

In the spring I proceed in this way. I first screw up the caps on the nozzles to make them as near air-tight as possible, and then open the gates clear up and close them again.

This answers three purposes: it runs the nut over the screw twice, and removes any accumulation; it determines whether the gate spindle and screw work freely at all points; it also compresses the air in the hydrant, and when the gate closes and the drip opens, the compressed air forces the water out, and will clear out most any obstruction that has accumulated from the outside, except

where the hydrant stands near a tree, and a root grows into the opening, as I have found in one or two instances.

If the hydrant does not work right, we locate the trouble and remedy it, and then remove and oil the caps. After this I find the hydrant will remain in good condition all summer. In the fall the operation is the same, except that we thoroughly oil every part, overhaul the packing and renew it if necessary, and pump the water out, noting, of course, if the gate is tight.

We use in the service a twelve-inch wrench, and every hydrant is supposed to open easily with that, but I find this would not be long enough in some places.

I visited a town some time ago where the fire department had done a particularly good job on a bad fire, and looking about the hose-house I saw a double-end wrought-iron hydrant wrench twenty inches long. I asked one of the men what they did with that, and he told me that was their regular hydrant wrench, and they carried a three-foot piece of gas-pipe to go with it.

Seeing by my face that I did not quite credit his story, he went to a box on the apparatus and showed me the pipe, which was about three feet long, and large enough to slip over the wrench. The chief, coming in just then, confirmed the man's statement, and said he had used the three-foot wrench, and three men, to open some of the hydrants, but that they were working a little better.

I think there must have been something the matter with the hydrants, or the man that had charge of them. There is one thing that can be said in favor of these hydrants, if those who designed them intended that they should work with an ordinary wrench, they allowed a generous factor for safety to stand three men on a three-foot wrench.

There are many cities and towns which own their works that credit the water department with a certain amount of money for hydrants, watering-troughs, etc. This I consider right. Other places do not allow the water department anything for this service. This I do not consider business-like or just to those that manage the works. It costs a city or town a certain sum to maintain its several departments, and each department has a separate account, and in the annual reports each department is expected to show how its money was expended, and the amount of work done. I think every department should stand on its own merits, and be charged with every item of expense belonging to it, and credited with all its work; unless this is done you cannot have a true report.

In the change of grade or relocation of a street, the hydrants must also be changed to conform to the new grade or location. Now, to what account should the cost of this work be carried?

In some places it is probably charged to the street and highway account; but in others it is charged to the water department, and carried to either the maintenance, repairs, or construction account, and it does not belong to either of them.

If the highway department expend one thousand dollars on a street, and the water department two hundred, it has cost twelve hundred dollars to improve the street; but if the work done by the water department is charged to their account, the report of the highway department will show that it cost one thousand dollars, which is not correct; the actual cost is the same in either case, but the water works get the short end of the stick.

If you ask for an appropriation for the care and maintenance of hydrants,

some one will tell you that the water works are doing well enough; that it will increase the taxes, and that they are high enough already. Well, let us see about this. Suppose that the revenue from the works do not pay all expenses, an appropriation must be made to cover this deficiency.

Now, suppose you appropriate this money for the use of hydrants, and the public use of water generally, it would not increase taxes or cost any more, but the works would receive the credit that rightfully belongs to them. But take another case. Suppose the works are self-sustaining, and with an appropriation for hydrants you have a surplus of six thousand dollars; now, what becomes of it? It is not lost; it will go back into the treasury, and be appropriated to extend the works, or for some other public use. But some will say, We do not want any surplus. Then reduce the price on the first faucets. This will affect those that are the least able to pay the water tax, — the man of moderate means, the man that depends upon his daily labor for a living, and from whom a large percentage of the revenue comes that supports the works.

The appropriation for hydrants coming from the general taxation, each one will pay for their maintenance in proportion to the amount of the property protected. The works should receive credit for every fixture from which water is drawn: from the faucet in the cottage to the hydrants that protect our business blocks and factories. Most, if not all, builders of hydrants claim them to be anti-freezing. Why? Because the opening called "the drip" is below or on a level with the supply-pipe, and when the gate is closed this drip is supposed to be open and to let the water all out of the hydrant post to a level with or below the inlet-pipe.

I say supposed, because you cannot see whether it lets the water all out or not; you can only guess, and you are apt to guess too quick if the thermometer is down to zero. This drip is like some boiler attachments that I have known; like non-sticking safety valves, low-water alarms, self-acting boiler feeds, which act all right just long enough to gain your confidence, but when you begin to rely upon them they go on a strike, and refuse duty, and you are in trouble right away.

There is one attachment to a hydrant that I consider necessary to make it anti-freezing that I have never seen mentioned in any circular or advertisement of hydrant builders, and that is, a suction pump with hose that can be introduced in the nozzle down to the bottom of the hydrant, and a faithful man to work it to make a sure thing of an uncertainty.

I am aware that in places where the drip can be connected with a sewer, or in sandy soil, there is less trouble or uncertainty about this; but in very cold weather, after a hydrant has been used, if immediately the cap is put on, the chances are that the frost and moisture will make the top of the hydrant air-tight, and the water cannot escape be the drip ever so free. I have made it a practice to pump out all hydrants after being used in cold weather, and if we have been working at a fire for any length of time, I try them twice, and sometimes more; for after a hydrant has been used for some time, the ground around the post is apt to be filled with water, and will give you trouble if you do not get it out. The question is often asked, How shall we set hydrants so they will not be liable to freeze?

This depends something on the place where they are set. Mr. Parker, of

Burlington, has said that the way to keep pipes from freezing is to put them below the frost; and our venerable friend, Mr. Jones, of Boston, remarked at one of our meetings that, after his long experience, the only sure way he knew of to keep pipes that were exposed to the frost from freezing was to let the water run or keep the water out. As we cannot place the whole hydrant below the frost, we can place the branch-pipe and gate there, and as we cannot let the water run, we must keep it out of the post. This seems easy, but like many other things, is more easily said than done.

In Marlboro' the soil is very springy; in some places we find this condition of things on our highest hills as well as the lower land, and in the places where we find quicksand the water stands within two or three feet of the surface most of the year. The hydrant drips here are not plugged, and they have never given me any trouble; but some hydrants, situated from one hundred to one hundred and fifty feet above this place, have filled with water to a level with the surface, and unless plugged and pumped out would freeze the first cold night. We could probably have kept some of them from freezing by the use of salt or oil, but the corrosive action of salt on iron, and the bad effect of oil on rubber hose, makes the use of them undesirable; but there are times when heroic measures are necessary, and then oil, salt, or most anything is advisable until you can do better.

We have 245 hydrants on our works, owned by the town, all of one manufacture, and not one of these have ever stuck, leaked, or needed repairs from any fault of design, material, or workmanship, or caused a moment's delay to our fire department in getting water at any fire since thay were put in commission. A frozen hydrant is not a desirable thing to have on your works; just the fact of a frozen hydrant is not so bad, for you can very soon thaw it out, but a frozen hydrant and a fire in that vicinity at the same time is what makes the cold chills run down your back, and makes you wish you were out of town, and that somebody else had charge of the works; for it is very much like the way some people look at a lie or a theft, — it is not the act, but being caught, that troubles them the most.

During the cold weather of the winter of '87 and '88, that made the coal-dealers grow fat and your coal-pile look sick, and every superintendent in New England was praying for warmer weather, I had a little experience that convinces me that no ordinary care will insure you from frozen hydrants. During that cold spell I was testing hydrants every day and almost every night, and a hydrant wrench was my constant companion. One night I started for home about 12 o'clock, feeling sure that every hydrant was in working order. On my way, by mere force of habit, I dropped my wrench on to a hydrant that I had tested during the day, that had not been used, and I knew that the gate was tight; in fact, I would have wagered considerable it was all right and ready for business, for it had never given me any trouble; but I found it as solid as a rock. This puzzled me somewhat; there was nothing to do but to thaw, and pump it out, and I found the water in the post within one foot of the surface of the street; I put in a quart of oil, and went home a sadder, and perhaps a wiser man, and I began to think that you could not place much reliance upon anything, and hydrants in particular.

The next morning I found the hydrant all right, and a solution of the problem. The service-pipe that supplied the building opposite the hydrant run up the

hydrant trench that was blasted out of a ledge. The waste-pipe from the building froze up, and they let the water run under the building, as they left their faucet open a little to keep it from freezing, and the water followed the pipe down to the hydrant, and filled up the post; after this was remedied, I had no more trouble at this place.

There is some difference of opinion, probably, as to which make of hydrants is the best. We all try and make the best of what we have, and probably there is no one that has charge of hydrants of any kind, for any length of time, but what has found some defects, or thinks he sees where an improvement could be made. We all agree that a hydrant should be well proportioned, to deliver the maximum amount of water with minimum friction or loss of head, should be strong in all its parts, to stand the rough usage in the hurry and excitement of a fire, of pleasing design and interchangeable parts, and easy of access for inspection and repairs.

The Lowry hydrant set over a branch in the main, it seems to me, is one that would deliver the maximum amount of water with the minimum friction or loss of head; also its close proximity, the water circulating in the main is favorable to prevent its freezing. Situated in the street, it is also convenient to attach two or more steamers, and in places where pressure makes the use of steamers necessary; and under certain conditions, such as public squares, or streets with high and massive buildings, where it would be desirable to mass a large force to fight an extensive fire, it is preferable, perhaps, to any other.

But under most any other condition, a good post hydrant is, in my opinion, preferable. It is more easily found, all ready to attach, and get right to work.

In talking with one of the oldest engineers of the Boston Fire Department, and commenting on the many devices employed and the ingenuity displayed to reduce to the lowest possible terms the time required to get the men and apparatus to a fire, he said, "We used to be after minutes, but we are after seconds now." It does take time, and valuable time very often (although it is done very quickly), to find, remove the cover, and adjust the chuck on a flush hydrant.

A post hydrant can be easily found and attached to, and if placed near the corner of a street is almost as easy to attach two or three steamers as though it stood in the street.

It would be a very nice thing if somebody would invent a dial or indicator to place on a hydrant, with a pointer, which, standing one way, would say, "I am all right," and the other way, "I am stuck or froze up;" but we shall not get this very soon.

If I were to write specifications for a lot of hydrants, there are three things that I should insist upon, and these are: that the gate should close against the pressure, that the opening for the drip should not be below the top of the inlet-pipe, and that the gate-rod should extend down to the centre of the inlet-pipe, so that in moving the nut on top with a hydrant wrench you would move the whole rod. My reasons are these: the gate closing against the pressure, comes to its seat without shock or ram; the drip being on a level with the inlet-pipe holds the water in the base to the same height as the inlet-pipe, and if the hydrant freezes it holds the gate-rod so it cannot move. There is a certain amount of movement (or, to use a shop term, back lash) between the nut and screw, which allows the gate-rod to turn a little without starting or disturbing the gate, and the end

of a twelve-inch wrench will have a movement of from three to six inches back and forth, without bringing any strain upon the gate.

I try my hydrants in this manner: I place the wrench on the hydrant, and if it is frozen the rod will be as solid as though it was held in a vice; but if I can move the rod with the wrench, I am absolutely sure that the hydrant is all right, and I can test them as fast as I can walk along the street. By this method, if the hydrant is all right, you do not let any water into the post, start the gate, or disturb its condition; and in this case, like many others, I think it is a good thing to let well enough alone, which you cannot do if you are obliged to start the gate to determine whether it is frozen or not.

All hydrants will need considerable care and attention, in severe cold weather, to keep them in proper order, until we have a perfect hydrant; and we shall not get that until we have a perfect man to build it, and that will not be this year.

DISCUSSION.

Mr. Richards. — I agree with all that Mr. Stacy has said with regard to the inspection of hydrants, and for the benefit of the water commissioners who may be here and those who may read the proceedings of this Convention, I desire to emphasize the uselessness of inspecting hydrants if you allow their use for filling watering-carts. The water commissioners ought to take that and reflect upon it.

Mr. Brackett. — In Boston this question of allowing the filling of watering-carts has been agitated during the past year. It had been the custom of the street and health departments to use the hydrants throughout the city for sprinkling the streets, and of the sewer department to use them for flushing the sewers. Contractors also were in the habit of drawing water from the hydrants when constructing sewers or other work, and the result was that some of the hydrants were found to be broken. About a year ago an order was issued that no one should use the hydrants without a permit. The health department is now granted permits to use them for filling their carts in connection with the street sweeping, and permits are given to a few of the employees of the sewer department for use in flushing sewers. The men who hold permits are obliged to show them to the police, and all police-officers are expected to stop and to report any person whom they find using a hydrant without a permit.

Mr. Darling. — Mr. President, I might say a word, perhaps, on this subject. It is one of the interesting subjects we all have to do with in practice, and we find various difficulties arising, and conditions which we do not just like, with regard to the hydrants, especially if the water department is expected to keep the hydrants in proper repair and ready for use. In the winter time we have charge of the hydrants, the fire department simply using them when they have to, and not being expected to have any control of the hydrants under any circumstances. Of course it is impossible to prevent hydrants freezing under some circumstances. I never allow them to be opened in extremely cold weather. I think it is a dangerous thing to do, for if you open a hydrant in very cold weather, it will certainly freeze before it can be used again, so we have given up the idea of opening them in the winter. We take the chances. We inspect the hydrants late in the fall, in the beginning of cold weather, and take the chances, not touching them again until spring. For the past four years that has been our

rule, and there have been good results. We have found but very few that were frozen, and those were located in ground where the surface-water would get into the hydrant, and then in some cases we have found the hydrant-stem frozen up perfectly tight. Of course the firemen, when they came to it and found its condition, would leave it and go to the next one, and it would be reported to us, and we would thaw it out.

Some three years ago our town began the experiment of watering the streets, and it was a question whether they could afford to do it or not, — previous to that time it had been done by private subscription, — and they wanted to use the hydrants. I allowed them to do it if they would put on proper men to handle them, and we didn't meet with much inconvenience from it. But I was fearful that we would, and so I asked the city government to erect standpipes to supply the watering-carts. They did so, and we now have more than forty in the city. I took care, however, to get rid of the responsibility of locating them before this man's house or that man's house by generously leaving it to the highway department. [Laughter.] They located them where they pleased, and although there are those who object to them, still they remain there just the same. They had got to be somewhere, and the highway department adopted the plan of locating them as they would hydrants. We have had some complaint from men who objected to having hydrants in front of their houses. I remember one gentleman objected on the ground that if his house got on fire the department could not use the hydrant in front of his house, and so he preferred to have it somewhere else near by. But on the whole, the plan of locating the standpipes as we locate the hydrants has given general satisfaction, and I think it is the only proper way to do. I do not believe at all in allowing anybody outside of the water department and the fire department to interfere with the hydrants; and with us even the owners of private hydrants cannot use them without first coming to us and getting permits to open them.

Mr. Brackett. — I should like to inquire how far apart it is the practice of members to set standpipes?

Mr. Darling. — We put them from one thousand to two thousand feet apart, varying in different localities.

Mr. Clark. — I would say that we place our hydrants about eight hundred feet apart, as a general thing, but in the centre of the city we place them more nearly together. I would like to ask this question: What remedy is there for the filling of the valves of the hydrants with water where the water stands in the ground, and there are no sewer-pipes to take it away. We make a practice, when we find that is the case, to plug them up, and then open them again in the spring.

Mr. Brackett. — That, I think, is the universal remedy. There is one difficulty which is experienced with the Lowry hydrants, and that is, if the wastes are plugged, we are obliged to pump them out after rain-storms and thaws, because the water fills the boxes and flows over the tops of the hydrants which are open.

DESCRIPTION OF THE WATER WORKS AT RICHMOND, VIRGINIA.

BY

CHARLES E. BOLLING, Superintendent.

In the year 1830 the city of Richmond, with a population of 16,060 people, decided, by a vote of the citizens, to construct water works. The City Council engaged Mr. Albert Stein, formerly a resident of Philadelphia, to prepare a plan and estimate of the cost of the works. A brief description of the city is necessary to clearly understand the situation. Richmond is on James river, at the head of tide-water. The topography of the site is exceedingly varying, consisting of a succession of hills and valleys, with elevations differing as much as one hundred and fifty-five feet. From the head of tide-water the river channel rises rapidly along a rocky bed, and within the distance of one mile and a quarter the water has attained an elevation of forty feet above mean tide. At this time a portion of the James river and Kanawha canal had been constructed along the northern shore of the James, and its water-surface was eighty-three feet above tide. At this point Mr. Stein selected a site for the pump-house, and recommended to use the water in the James river canal as a power, the surface of the canal being about forty feet above the proposed site. Subsequently the plan was changed, and water was obtained from a small fore-bay at the river, parallel with the canal and below it, and about 500 feet along. This fore-bay was supplied with water by means of a wooden dam, built on the rock ledges, and furnishing a head of ten feet. Here Mr. Stein erected a pump-house and pump. The water-wheel and pump were furnished by William Kemble, of New York. The wheel was a low breast wheel, and worked a double-acting horizontal pump of 400,000 gallons capacity in twenty-four hours. From the pump-house an eight-inch water main was laid under the canal to the reservoir, situated on a hill 2,400 feet distant, and 160 feet above the pump. The reservoir was 194 feet by 104 feet by 10 feet 8 inches deep, and was divided into two equal compartments by a brick wall; the enclosing banks were clay, and its capacity was one million gallons. In one compartment a filter bed, 32½ feet by 16 feet and 3 feet above the bottom of the reservoir, was constructed. The bed consisted of layers of coarse gravel at the bottom, the finer gravel and sand on the surface. The water by means of the pipe arrangement was to be forced upward, and finally find its way over the division wall into the distributing compartment. For the purpose of cleaning the bed, it was so constructed that water could be admitted from the surface, and wasted through the pump-main by means of a *waste* branch into a ravine. Mr. Stein stated at the time that this was the largest filtering bed in the United States; also that he was doubtful of its proving successful. The surface of the water in the reservoir was eight feet higher than any point in the city, and water was conducted to the city by means of a supply main 10 inches in diameter, 6,175 feet long. This main was estimated to deliver 400,000 gallons in twenty-four hours, or, according to Mr. Stein's calculations, furnish water for 4,000 families, computing the daily consumption to be 100 gallons per family. From the terminus of the 10-inch

main numerous distributing pipes of small diameters were laid, and fire hydrants put in at convenient points. The total cost of the works, — pumps, reservoir, pipes, etc., — exclusive of the dam and fore-bay, was $76,860. The works were accepted by the city February 17, 1832.

In 1833 another water-wheel and pump of the same design and capacity were erected, and another eight-inch water main laid from the pumps to the reservoir. In 1835 the filter bed was pronounced a failure for the purpose of purifying the water, and its use abandoned. In 1839 the city bought the dam and fore-bay for the sum of $25,000; and five years afterwards replaced a portion of the wooden dam with one of stone. In 1843, the population then numbering 23,000, the reservoir capacity was increased to 7,000,000 gallons, by raising the banks of the old reservoir and adding a new addition. In 1848, the supply of water becoming limited, — the population was 25,716, 1,212 of whom were water-takers, — a new supply main, twelve inches in diameter and 6,175 feet long, was laid. In 1849 the pumps were again increased by the addition of two water wheels and pumps of the same design and a little greater capacity, and two eight-inch mains laid from the pumps to the reservoir. Five years elapsed before it was again necessary to make additions, when two pumps and wheels of the same design, but of a capacity of 2,264,386 gallons per day, were put up, and two twelve-inch mains laid to the reservoir. The water-takers at this time numbered 1,882; the total pumping capacity was 4,453,107 gallons in twenty-four hours, and the reservoir capacity 7,000,000 gallons. In 1860 a twenty-four inch supply main was laid from the reservoir to the city. No further additions were made to the works until 1873; the supply then becoming scarce, owing to the increased number of water-takers, the population being 56,800. During the years 1873 and 1874, under the superintendence of Emile Geyelin, two horizontal double-acting pumps, having seventeen inch cylinterets and six foot stroke, were erected. These pumps were run by a Jonval turbine wheel. Their capacity was estimated at three (3) million gallons in twenty-four hours. A steam-pump, constructed by Guild & Garrison, of Philadelphia, with a capacity of 800,000 gallons, was erected on the canal, near the old pumps, and a twenty-four inch main laid to the reservoir, into which the new water-power pumps and steam-pump discharged. Upon their completion the actual pumping capacity was 7,557,943 gallons daily, the consumption 2,517,477 gallons, and the rate *per capita* $44\frac{2}{5}$ gallons. The city at this time was rapidly extending and being built up in the higher portions, differing in elevation very little from the site of the reservoir, and was supplied by mains laid along streets of widely differing grades, greatly limiting the supply to those living on the high points. The demand came for increased pressure. Up to this time no plan to meet the future wants and growth of the city had been considered or adopted, but step by step, as the population increased, pumps and mains had been added to meet the necessity.

Col. W. E. Cutshaw, city engineer, after numerous surveys and examinations, recommended a site and plan for a new reservoir, which was adopted by the council, and constructed under his direction during the years 1874 and 1875. The site was a high and level plateau, about one mile west of the old reservoir, and two-thirds of a mile from the river, conveniently situated for a new pump location, which would have to be selected. The new reservoir is rectangular in shape, and contains 40,000,000 gallons, and is divided into two equal compart-

ments by a division bank. The banks are twenty-four feet high, and are composed of good puddle clay, which was thoroughly consolidated by rolling with corrugated rollers after being spread in thin layers. The inner slope is two to one, the outer one and one-half to one, and carefully turfed. The inner slope is paved with bricks laid on edge with hydraulic cement. On the top of the banks there is a gravelled roadway, twenty feet wide, margined on the water side by a granite coping and iron fence. The bottom of the reservoir is concrete, six inches thick, which is from three to four feet lower than the flow line to the city, and has a gradual fall towards the centre of the northern bank, where two cast-iron waste mains pass through the bank.

In the division bank there are constructed two chambers or wells. The influent chamber, near the south bank, is built of brick and stone, and the gates so arranged that the water can be pumped into one or both compartments at the bottom, or allowed to rise and flow into either basin down stone steps set to the angle of the slope. From this chamber two 30-inch cast-iron mains pass through the southern bank. The effluent chamber, near the northern bank, built of brick and stone, has three gates on each side (with screens), at different elevations opening into the two compartments. Two 30-inch mains pass from this chamber through the northern bank. The floors of the influent and effluent chambers are three and four feet above the bottom of the reservoir, thereby providing for a large settling space in each basin. On the outer slopes of both banks there are stone vaults, in which are placed the valves. The surface of the water is thirty-seven feet higher than that of the old reservoir, and forty-two feet above the highest point in the city. A 24-inch main, passing alongside the old reservoir, leads to the old pumps, and is connected by separate connections with the old reservoir, and the 24-inch main to the city, in order that it may be used either as a pump or supply main. From the north side of the new reservoir a 30-inch main, having a gradually descending grade, is laid to the city, and along this main are numerous valves and branches, providing for future extensions. The reservoir was completed and put in use January, 1876. Four years after its completion, the consumption had increased to 5,849,894 gallons, and the rate *per capita* per day was 92 gallons. More pumps were needed, the present pumps being in need of repairs, as the tax upon them, pumping through a long and tortuous main to the new reservoir, was very heavy. Surveys for a new pump site were made by Col. Cutshaw, city engineer. It was ascertained by him that, to supply the reservoir by gravitation, a conduit costing several million dollars, and from seventy to eighty miles long, would have to be built. So this idea was abandoned. He finally recommended a location for the new pump-works, on the James river and Kanawha canal, from which power would be gotten, two miles west of the old pumps, and two-thirds of a mile from the new reservoir.

In 1880 the council approved the plan, and under his direction the work was commenced and finished. At this point there were two locks near together, each having a lift of ten feet. A new channel was cut around the locks, which gave a head of twenty feet. A channel was also cut around a third lock about two miles farther west, and a head wall and gates put in. The canal channel was deepened and widened for a distance westwardly 6½ miles; and a feeder at this point, leading from the canal to the river, was also deepened and widened. The feeder entered the river about 1,000 feet above Bosher's dam, a substantial dam

already built and used by the canal. At the junction of the feeder and canal a granite head-wall with gates was erected. The area of the channel was enlarged to a capacity of 705 cubic feet per second. A substantial stone pump-house of Gothic design was erected, and a head-wall, with waste-gates, built at the lower end of the fore-bay. The flow of the canal is nearly three times the quantity required for the present pumps. After a careful examination of various competitive designs for pumps and water-wheels, a combination submitted by Prof. Chas. A. Smith, of St. Louis, was selected, and with some modifications and changes, the machinery was put up by H. A. Ramsay & Co., of Baltimore. The water-wheel is a vertical partial turbine, 23 feet 7½ inches in diameter, perimeter 20 inches wide, buckets concave and 23 inches deep. The wheel revolves vertically. Water is brought to the wheel by a flume 5 feet in diameter, and connected by a goose-neck bend with a large guide chamber and diffuser at the base of the wheel, so as to deliver the water at right angles to the buckets, and acts on about one-eighth of the circumference at once. The buckets and diffuser are so shaped as to lose the water as quickly as possible after its action upon the wheel. A shaft 18 feet long and 12 inches in diameter extends only on one side of the wheel. Upon the shaft are three crank arms, set at an angle of 120 degrees to each other, and of such length as to make a six-foot stroke of plunger; they are so proportioned that the moment one pump ceases to deliver, another commences, therefore the revolution is perfectly uniform. The pumps are single-acting, vertical plunger pumps, fourteen inches in diameter; each pump is supplied with three cornish valves, — suction, intermediate, and discharge. The pumps are connected by 20-inch diameter branches, with a 36-inch suction main, charged under a 20-foot head, and deliver into 30-inch main, passing under the fore-bay, and rising, by a gradually ascending grade, 161 feet to the new reservoir. There are three wheels and three pumps to each wheel, each set having a capacity of 4,000,000 gallons, or a total capacity of 12,000,000 gallons in twenty-four hours. At their maximum rate the wheels make 20 revolutions per minute, and require 285 cubic feet of water per second. The water necessary to run the pumps is discharged into the Richmond level of the canal, and is again used by several manufactories and mills in the city.

During the construction of the water-power pumps, and under a demand for immediate supply of water in the drought of 1881, a Worthington Duplex Compound Steam Pump, with a daily capacity of 6,000,000 gallons, was erected. This was the pump used at the Exhibition grounds, in Philadelphia, in 1876. It is now rarely used, but kept in good order, as a reserve in the event of accident or damage to the canal by high freshets in the river.

It will be seen from the foregoing description that the pumping machinery of Richmond is of various designs. At the upper station there are three vertical partial turbine wheels, with single-acting vertical pumps, and a Worthington Duplex Compound Steam Pump. At the lower station there are six old-fashioned, low-breast water-wheels, working six double-acting horizontal piston pumps, and a Jonval turbine wheel, working two horizontal double-acting piston pumps. The Guild & Garrison steam pump was sold. The pump mains are so arranged or connected that one or both plants can be used to supply the higher reservoir, or the lower reservoir can be filled from the new reservoir.

The city distribution is divided into two services; the high service is supplied from the new reservoir, the low service from the old reservoir. The daily consumption of the high service amounts to 7,500,000 gallons, the low service to 3,500,000 gallons. The maximum pumping capacity is 24,000,000 gallons per day. The total storage capacity is 49,000,000 gallons. There are 28,700 lineal feet of pump mains, 10,981 lineal feet of supply mains, 70.7 miles of distributing mains, and 9,850 taps or water connections. The present population is estimated at 90,000, and the daily consumption 11,311,013 gallons, and the rate *per capita* 126 gallons. It will be observed that the city has now a pumping capacity more than double the daily consumption, and if the waste was reduced and the daily consumption brought even to a liberal quantity, say 60 gallons *per capita*, the pumping capacity would be nearly five times the daily consumption.

I will say in closing that the water works in Richmond are one of the oldest in the United States. In presenting this description to the Convention I have endeavored to make it as brief as possible, and if there are any points which are not clear to any of you, upon which you would like further information, I would be very glad to answer any questions which may be asked me.

DISCUSSION.

Mr. Clark. — I should like to ask what the quality of the water is.

Mr. Bolling. — The water is perfectly healthy, but for two-thirds or three-quarters of the year it is unattractive in appearance. It is healthy at all seasons, for we have had it carefully analyzed by different chemists, but it has the appearance of being muddy, although it is not muddy. One or two of the tributaries of the James river flow through very red lands and very fine soil, and for miles and miles above is a rocky channel over which the water flows, and the water gets so colored that it never becomes perfectly clear. But after the sand and heavier sediment has been removed, which is provided for in this reservoir, we get water which is colored, but pure.

The President. — How often do you have to clean the reservoir?

Mr. Bolling. — We have not cleaned our new reservoir since we built it, but we have carefully measured the rate of deposit, and it has averaged an inch a year since its construction, in 1874. I have stated that our power, as well as our supply, is brought down the old canal for a distance of six and a half miles, and we carry into execution there very much the same idea that Mr. Babcock recommended at Little Falls, N. Y. There is a large amount of water stored above Bosher's dam in the river, from which we take probably twenty-five per cent. of the average flow of the river. And, in order to secure the benefit of the purification of the water, three different sets of head-walls and gates were built around the canal, the old locks themselves forming dams, as it were, so as to allow the water to flow with tremendous velocity through the gates, equivalent to having a fall over a dam, and to be thoroughly turned over; and then in the more quiet current from that point to the pumps it is given an opportunity to settle. And there is no question of the value of this, for ever since I have had charge of the works I have had samples taken at various times from the river above Bosher's dam, at different points in the canal, at the pump-house fore-bay, in the reservoir,

and at the hydrant. The water in the fore-bay, in appearance, is better than that in the river, in analysis it is a great deal better, and after having had four days to settle in the reservoir, it is better than in the fore-bay.

Mr. Babcock. — May I ask, Mr. Bolling, if there is any difference in the temperature of the water at the time it passes the first dam and when it finally passes the last one?

Mr. Bolling. — Yes.

Mr. Babcock. — The difference in the temperature would indicate whether there was any oxidation going on?

Mr. Bolling. — There is a difference in the temperature.

Mr. Babcock. — That shows that the dam is producing a good effect in oxidizing the water, and is precipitating a certain amount of impurities which would create heat, and thereby raise the temperature of the water. I think that is the fairest test as to the purification of water by aeration. I discovered the same thing at Little Falls, that there was a very marked change in the temperature from the beginning of the canal to the end, and I am glad to know you have found the same result.

FRICTION IN COLLECTING METER RATES.

BY

Geo. F. Chace, Supt., Taunton, Mass.

Careless and wasteful consumption, and consequent deficient supply, is a common experience of water departments.

An obvious remedy, and one now often adopted, is the compulsory use of meters. When not compulsory, their use is generally encouraged in all practicable ways.

Papers have been read before this Association, calling attention to defects in these machines, — defects which result in loss to water companies from under-registration.

Another side to the question might be presented. When meters are kept in good working order, and are substantially accurate, consumers are sometimes astonished at the size of their rate bills, because they are asked to pay for all the water, which, according to the dial, has passed through the meter, whether that water was a legitimate or wasteful consumption, or had been passed off in leaks of which the proprietor was not aware.

Then is likely to ensue "Friction in Collecting Meter Rates."

How to stop waste and yet avoid trouble with the consumers; how to diminish friction between the consumer and collector, and yet to exact justice; how to keep peace and harmony between the citizens and water officials; to secure the confidence of the former in the efficiency of the latter, — are questions to which this paper seeks to find an answer.

Patrick Henry once said he knew of no way of judging of the future but by the past; which was only another way of saying that men should be guided in their actions by the results of experience.

Perhaps the experience of the water department of Taunton, in relation to

the subject of this paper, may not be without some general interest, and may afford the most useful means of giving hints for practical guidance.

Meter rates in Taunton are payable annually, January 1–20, except that very large consumers pay quarterly. Readings of all meters are taken once a month. For several years it has been customary each month to notify persons whose meter readings indicated an excessive consumption. For a year or two previous to January, 1888, these notices were sent by postal cards, bearing a printed form. At that time a case occurred of excessive consumption, owing to a bad leak.

A postal card was sent to the consumer, but he claimed that he had never received the notice, and requested an abatement of his bill, on the ground that, if he had been properly notified, he might have stopped the leak and saved himself a large expense.

Not wishing to take advantage of the misfortune of a citizen, the commissioners granted the consumer a liberal discount from the face of his bill, but directed the clerk thereafter to send his notices by autograph letters which should be copied in a special copying book.

From that time until January, 1889, it was the practice for the foreman to look over the meter-book, on its return by the inspector, and to report at the office such cases as he had observed of excessive consumption. Notices were then written by the office assistant, in the name of the clerk. (For the sake of clearness it may be well to state that the officer styled in many water departments "Registrar," in Taunton is called "Clerk," and since 1883 the clerk has also been superintendent.)

Notwithstanding these attempted precautions, several instances occurred in January last where the meter-bills were large from an unusual consumption, without a notice having been sent to the consumer.

Although the sending of notices was regarded by the commissioners merely as an act of courtesy which they were not bound to perform, yet the consumers felt aggrieved, on receiving a bill, the amount of which was an unpleasant surprise.

The method pursued by the writer, in adjusting such difficulties, may be best understood from one or two examples.

Mr. M. is the proprietor of a tenement-house of which the service is supplied through a meter. From this house a pipe runs underground to another in the rear, — both services being thus supplied through the same meter. In January, 1888, Mr. M.'s bill for this service was $12.18. In January, 1889, it was $39.73. The number of tenants had been smaller in 1888 than in 1887. Naturally this man was surprised and reluctant to pay an amount more than three times as large as he had expected. An examination of the letter-book disclosed the fact that no notice for excessive consumption had been sent. The underground pipe between the houses was very suggestive of a chance for a leak. A cheap class of tenants might have been careless and left faucets running in the winter to prevent freezing, or in the summer to cool the water. But whatever the cause, the surprise remained. The matter was compromised by throwing off the odd $9.73, — thus reducing the bill to $30, an amount still large in comparison with $12.18. Subsequent events proved that there had been no leak, but carelessness on the part of the tenants. In this case the meter was a $\frac{5}{8}$-Union Rotary, set August, 1885, and has never been out for repairs.

Mr. F.'s bill for January, 1889, was $24.50, while in January, 1888, it had been only $10 for the same service. This again was a great surprise, as during the summer of 1888 the family of F. had been in Europe, and the water was shut off. The correspondence between Mr. F. and the clerk of the water commissioners will best explain how this matter was adjusted: —

"TAUNTON, Dec. 28, 1888.

"*My Dear Mr. Chace:* — An employé of the water board was at my house yesterday to look at my water-meter, and said that there had been a sudden jump in the amount of water recorded this year, sending the bill up from the usual $10 to $25. A similar thing has occurred once before, in 1884, carrying the bill up to $18.50. Every other year since I have lived here, the consumption has come within the minimum charge, and in that year, 1884, I had used less water than usual, from the fact that it was a wet season, and I had not used the hose much in summer. This year it has not only been wet, so that I have used the hose hardly at all, but I was absent from the middle of July to the middle of September, and shut the water off outside of the meter. There has been a slight leakage in the water-closet upstairs this fall, and I have been waiting some time for the plumbers to come and fix it; but it is entirely inadequate to account for the excess of water recorded, in view of the fact that there has been so much less used this year than is usual.

"Doubtless the water board has full faith in the integrity of water-meters, but my confidence in them has become sadly shaken. I paid the excess in 1885, because I could not say certainly that the meter lied; but inasmuch as it went back at once to the old rates, and has remained there ever since, in spite of the fact that I have not been sparing of water, and has only undertaken to come its little game on me this year, when I have been absent a month longer than usual, and have had no need of water for the garden, I feel morally certain that it is not to be depended on for absolute moral integrity. Some leakage there has been, but I cannot think it could possibly add $15 to my usual consumption.

"Yours very truly,

"———."

To this letter the following answer was sent: —

"TAUNTON, Dec. 31, 1888.

"DEAR MR. ———: —

"I find it has been customary to read the meter at your residence about the tenth of each month. During July, August, and September no readings were made, as our agent was unable to gain entrance. From June 10 to October 10 there were run through the meter, according to our records, 3,526 cubic feet. This is the difference between the June and October readings.

"You say you shut the water off outside the meter from the middle of July to the middle of September. That would leave from June 10 to July 15, and from September 15 to October 10 to account for 3,526 cubic feet.

"The inspector reports to me a leaky water-closet. You admit this, but think the leakage entirely inadequate to account for the apparent large consumption.

"Not trusting to theories, this afternoon I measured the water flowing in a stream one-sixteenth inch in diameter, under the ordinary domestic pressure,

within a given time. The result was a gallon in twenty-eight minutes. At this rate we should have in sixty days, 3,085.8 gallons = 412.55 cubic feet. 3,526 ÷ 412.55 = 8.5 +. The flow of a stream, of course, varies with the square of the diameter of the orifice.

“ $\frac{1}{5} \times \frac{1}{5} \div \frac{1}{16} \times \frac{1}{16} = 10.2 + \frac{1}{6} \times \frac{1}{6} \div \frac{1}{16} \times \frac{1}{16} = 7.1.+$

“ Therefore, the leakage of a stream between one-fifth and one-sixth inches in diameter would account for your large consumption.

“ Yet, although I am inclined to think the meter is not in error, I can safely assure you that the commissioners will not desire to be sharp with an honorable gentleman, whose consumption has been large, not on account of negligence on his part. When I state the facts to them next Saturday evening, I have no doubt that, under the circumstances, they will be ready to make some abatement. If you can inform me before that time that the leak has been stopped, that fact might influence their minds in determining the amount of abatement.

“ Yours truly,

“ GEO. F. CHACE.”

This communication brought the following answer : —

“ TAUNTON, Jan. 3, 1889.

“ DEAR MR. CHACE : —

“ Your courteous letter of the 31st December was received and studied. I have been trying to get the facts in the case ‘ down fine,’ and find them to be, as nearly as I can make out, thus : —

“ 1. I am not aware of any leakage before the summer vacation.

“ 2. I find that we left the house July 19, at which time I shut the water off, as I supposed, at the entrance to the cellar, beyond the meter. But my wife, who came back to the house July 30, after eleven days, found there had been some leaking at the vent-hole of the cut-off, and sent for the plumber, who said the water was not shut entirely off. I had turned the screw until it stopped, and supposed it was quite tight, but it proved to have needed an extra wrench. That, however, could not have left much of an opening, and it was entirely stopped on the 30th of July, so that from that time there can have been no leakage within the house. The 3,526 cubic feet must then consist of the water used from June 10 to July 19, — the leakage from July 19 to July 30, — and the regular usage from Sept. 15 to Oct. 10.

“ 3. The leakage in the water-closet is recent, and the amount only a dribble.

“ 4. I found, one day, a dribbling from an outside sill-cock ; that was early in the fall ; I turned it off at once, and it has been shut ever since.

“ 5. Last Monday the plumber came and went over the whole business, and I think it is now as tight as a drum.

“ I have given you thus, as carefully as I can, all possible sources of waste. It does not seem to me possible that there has been sufficient to add $15 to my usual $10, considering the fact of a long absence and the failure to use the hose as usual. It may be that it is my ignorance of the nature of the case that makes me think so, and if so, I am ready to pay my dues.

“ I leave the matter to you and the Board with entire confidence.

“ Yours very truly,

“———.”

As a result of this correspondence, the gentleman's bill was reduced from $24.50 to $15, thus dividing the chances of error between the consumer and the water department. This arrangement was entirely satisfactory, and the bill was settled without further controversy. It may be interesting to note that, in this case, the meter was ½-inch Crown, set June, 1882, and had never been out for repairs.

In a few instances besides those mentioned at the January settlement, persons objected to paying their meter bills, on the ground that they were excessive, and that there must be a mistake on the part of the water officials, or something wrong with the meter.

But by showing them from the letter-book that they had been duly notified of excessive consumption, yet had neglected the notice, and by sending to examine their premises an inspector who discovered a good-sized leak, or detected, on the part of tenants, proceedings which wasted much water, by going over the record-book month by month, and showing them just where the large consumption occurred, one by one they came into line and cashed up, generally in perfect good humor, and never with anything more serious than a slight reluctance and a mild protest.

Desiring to avoid in the future all chance for debate as to the justice of bills, and to make sure that the work was thoroughly done, every month, beginning with February last, as soon as the meter readings have been returned by the inspector, the writer has personally examined every reading. Whenever the monthly consumption, as shown by the difference of readings of two successive months, exceeded the proportional part of the minimum rate of $10 per year, the register number, name, street number, and consumption in feet were copied upon a sheet of paper. When a list had thus been made of all such consumers, omitting quarterly meters, the record of 1888 was examined with reference to each one of those names upon the list, and the monthly average for each for last year written on a line with that of the month in question of the present year. When there was little difference in the figures, the name was erased from the list, but if the monthly consumption was considerably above the average, the names were retained and this revised list handed to the office assistant, who sent notices to each one, according to the following model: —

"FEB. 10, 1889.

"MR. JOHN SMITH:

"*Dear Sir*, — Our meter inspector reports that the registration of your meter at 3040 Commonwealth avenue shows an excessive consumption for the month of January, 1889, namely, 15,000 gallons. We do not object to this, if it is known and understood by you, but if it exists without your knowledge and consent, we would suggest that an investigation now may perhaps save annoyance and a large bill at the end of the year.

"Yours respectfully,

"GEO. F. CHACE,

"*Clerk.*

"Per C."

Up to May 25, 1889, the Taunton Water Department had in service 892 meters. The number of notices sent thus far in 1889 has been as follows: January, 78; February, 7; March, 26; April, 18; May, 40.

What has been the result? Some, doubtless aware that they were using considerable water, have said nothing. Many have expressed their thanks for the courtesy, and said they had discovered leaks which accounted for the over-consumption, and were glad to know the fact and have the leaks repaired. Others, of course, thought there must be "something wrong with the meter." When such a course was deemed necessary to satisfy the consumer, the meters have been tested. This Association does not need to be told that, in almost every case, the test showed the registration of the meter to be in favor of the consumer. Men of the department have been sent, without expense to the consumer, to see if leaks could be detected. Often they have been found, and the plumbers given a job of repairing.

When no leaks have been discovered, and the meter has been tested without satisfying the citizen, the hint has been thrown out that tenants might be careless in letting the water run, but would be slow to acknowledge the fact to a landlord who might thus be led to raise the rent.

Yet they might be more careful when they found they were under suspicion. A diminished consumption for the following month often proved the usefulness of such a hint.

During the past five months the discovery has been made that in reading nearly nine hundred meters every month, the inspector has in that period made five or six mistakes. Considering the darkness of cellars and the amount of the figures, such mistakes are perhaps somewhat excusable, especially as such errors are sure to betray themselves in subsequent readings.

With meters read every month, stoppages can be reported, defects repaired, and water-takers notified of a consumption excessive from whatever cause. Thus both the department and the consumer are protected from unnecessary loss.

The writer is engaged in preparing a record-book which shall contain a full account of all the meters ever used in the Taunton water works, the date and place of setting and of removals, with memoranda of causes of removal, and the readings when set and removed. It will thus contain a biography of each meter.

Another book is in preparation, to contain a record of all meter tests, and a tank and scales have been set up in the work-shop for the purpose of testing all new meters before setting, and others when out for repairs.

Seventeen different kinds of meters have been employed in the history of the works, and ten different sorts are at present in use.

By such means the department may be expected to have a good degree of knowledge of the value of machines of the various makers, and of the character of individual meters of the same maker.

Is it unreasonable to hope that the methods indicated in this paper will secure the confidence of consumers and diminish "friction in the collection of meter rates"?

At least this may be said: if care in keeping the records, faithfulness in repairs, patience and forbearance with the irritating criticisms of persons having less technical knowledge than the water official, frankness in admitting a mistake when one has been made, and polite firmness in adhering to the truth when the

official knows he is in the right, — if all these do not secure the confidence and support of a community, nothing else will.

If any suggestions have been made which may prove of practical value to members of this Association in the performance of their official duties, the object of the writer will have been accomplished.

RECENT PROGRESS IN BIOLOGICAL WATER-ANALYSIS.

BY

William T. Sedgwick,
Associate Professor of Biology,
Massachusetts Institute of Technology, Boston.

A biological analysis of water, strictly speaking, is an impossibility. Water may be analyzed chemically and resolved into its components, hydrogen and oxygen, but a biological analysis of water is an impossibility, because water is absolutely lifeless and inorganic. By a chemical "water-analysis," however, the chemist does not usually mean the analysis of a portion of pure water, but only a chemical examination of the substances dissolved in, or carried by, the water. In precisely the same way a biological "water-analysis" is understood to be simply *an examination of the organisms present in a particular portion of water.*

The biological analysis of a water must deal with all the organisms which can be detected therein; but inasmuch as the coarser water-dwellers, — the fishes, the frogs, the snails, the water-weeds, etc., — are seldom collected in a sample for water-analysis, there are usually present only the very small, and often quite invisible, organisms which may nevertheless be exceedingly numerous. Practically, therefore, the biological examination is directed to the inconspicuous forms of life, which often swarm in waters, even in those used for drinking. Taken as a whole, these organisms are known as the "microörganisms," and form a vast group of living things, some of them nearly, and some of them quite, beyond the vision of the naked eye. In dealing with the microörganisms in a sample of water, or in a water-supply, the coarser organisms must by no means be neglected; but the biological analysis of water as at present conducted is concerned especially with the microörganisms; and in the present paper no great departure will be made from the prevailing point of view.

Microörganisms are of two different kinds, and must be studied in two very different ways. Although all might perhaps be described as "microscopic" in size, those in one group are so much smaller than those in the other as to be almost smaller than "microscopic." These smallest microörganisms are the bacteria; and, although they may be seen by the help of the microscope, and, indeed, can be seen individually in no other way, they cannot be satisfactorily studied — still less counted — by the microscope alone. These microörganisms — the bacterial — are therefore detected and chiefly studied by the method of "cultures," otherwise known as "Koch's method," which I had the honor to describe and demonstrate at a meeting of this Association a little more than a

year ago. Of the bacterial microörganisms I shall speak to-day only incidentally, although within the year our knowledge of them and of their doings has been steadily advancing.

On this occasion I desire rather to turn your attention to the second division of the microörganisms, the microscopical. This includes all microörganisms except the bacterial, and is separated from that group by the fact that while the latter require for their satisfactory study the employment of "cultures," the microscopical microörganisms may be detected, counted, and pretty fully studied by the microscope alone.

In a summary fashion the relations of these groups may be shown as follows: —

MICROÖRGANISMS. Organisms, either plants or animals, too small to be studied with the naked eye.	MICROSCOPICAL. Not requiring special "cultures." Easily studied with the microscope. Microscopic in size, or barely visible to the naked eye. Plants or animals.
	BACTERIAL. Requiring special cultures for their satisfactory study. Difficult of study with the microscope, because almost sub-microscopic in size. Plants.

The bacterial microörganisms include the bacteria, as well as some yeasts and moulds. The microscopical microörganisms include a great variety of animals, such as minute entomostraca, like Cyclops and the water flea; various worms and wheel-animalcules; sponges and the fresh-water Hydra; infusoria, rhizopods, and such like; and among the plants, the diatoms, algæ, fungi (excepting those already mentioned), and the so-called "blue-green algæ." Beside the bacteria, these forms are mostly of giant size, and hence may be seen and studied with comparative ease by the aid of the microscope.

I am the more anxious to urge upon your attention the microscopical microörganisms, since it is with them that some of the more recent progress has been made in the biological analysis of water. Furthermore, it is in this field, in all probability, that some of the most interesting developments of the next year or two will be found. These are the organisms that often pave the way for bacteria in water, and possibly therefore, for the germs of disease. These are the organisms which are, in large measure, the source in water of the "organic nitrogen" (or albuminoid ammonia) of the chemists; the organisms, responsible in large measure, for odors, tastes, and turbidities in waters, either directly by their own activity, or indirectly by amassing organic matter, and eventually surrendering it as putrescible food for the more destructive bacterial microörganisms.

As long ago as 1850, Dr. Arthur Hill Hassall made a microscopical examination of the water-supply of London, perhaps the first ever scientifically made anywhere, and, in discussing his results, wrote afterwards, as follows: [1] "The deleterious properties of impure water depend, for the most part, on their *organic impurities.*

"Until very recently chemists did not, in general, attach sufficient importance

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[1] Food and its Adulterations, p. 55, London, 1855.

to these organic contaminations, and in most of their analyses we find the different kinds of organic matter, vegetable and animal, living and dead, all lumped together. . . . Indeed, chemistry is but ill-adapted to investigate the nature of these organic matters; it gives but a very rough estimate only of their gross amount, and does not discriminate, as we have said, the animal from the vegetable, the dead from the living," etc.

For twenty years after Dr. Hassall's day, his work remained almost alone. In 1870, however, Professor Cohn, the biologist, of Breslau, in an extremely suggestive paper on the "Microscopical Analysis of Well Waters," perceiving, perhaps, better than any one else has yet done, the profound significance of such studies, wrote as follows:[1] "There is no doubt that microscopical examinations of drinking-waters, properly conducted, will strengthen and perfect the chemical examinations at the most essential points, and that they only will give us information upon certain questions which the reagents of the chemist cannot answer."

As if to justify his assertion, Cohn immediately proceeds to compare the results of chemical analyses with his own observations of corresponding microscopical conditions, and, as might have been expected, with interesting results. There is even here, however, no prolonged comparison of chemical with biological results, and hence no such fertile outcome as might have been attained.

After Cohn's paper we find nothing so suggestive up to the present day. It stands alone, so far as I know, in a serious and enlightened endeavor to coördinate and render mutually helpful, chemical and biological data. With this one brilliant exception, little progress has been made in the interpretation of chemical and microscopical analyses of water (though of the former vast numbers have been accumulated), simply, I believe, because chemists, on the one hand, have been content to name the most complex and the most important substances in their analyses "organic matter," therewith resting satisfied; while biologists, on the other, instead of seeking a simple explanation for the presence or absence of organisms, or endeavoring to learn their chemical significance, have too often dissipated their energies in struggles to classify those organisms which they could name, and to name those which they could not classify. Doubtless, also, the rise of bacteriology, soon after the appearance of Cohn's paper, with the intense interest which it aroused, did much to distract attention from the microscopical microörganisms, and to fix it upon the bacterial. But even concerning the bacterial microörganisms interest has been thus far principally medical. The discovery that infectious diseases may be propagated in drinking-water, caused general alarm. Most bacteria, however, are not disease germs; and yet they are scarcely less interesting on that account, for by their presence they always signify something, and in their absence are hardly less conspicuous. Bacteria are fungi; that is, they are not green with chlorophyll, and, consequently, since they cannot build up food for themselves from mineral matters, as they might do if they had chlorophyll, they are obliged to live upon ready-made foods. If, then, a drinking-water contains bacteria, living and thriving, there is no escape from the conclusion that there is or has lately been ready-made food in that water. Well waters usually contain few bacteria; and this we would expect from their poverty in ready-made food, — which is only

[1] Beiträge zur Biologie, I., 109.

another name for some kinds of organic matter. River waters usually contain numerous bacteria, and ready-made food is generally there in the shape of organic matter of one kind or another.

Now it is precisely this ready-made food that the bacteria must live upon, and which they oxidize eventually to mineral matters, that the larger, microscopical microörganisms abundantly produce, as may readily be understood by reference to the diagram at the end of this paper. (Compare the diagram and the explanatory remarks appended.)

It is plain that, if the microscopical microörganisms often furnish the chief support of bacteria, they are worthy of the closest consideration. But until lately, however desirable their enumeration and study might have been, investigation of them was comparatively difficult. No good methods for their quantitative study have been known, and this, quite as much as the all-absorbing interest in bacteriology, has prevented their widespread study. Up to the present time the best methods have made no pretensions to be quantitative, and microscopical examinations of water have been usually directed to the sediment obtained by letting a given sample stand for a longer or shorter time. The suspended matters have thus been more or less completely disregarded. Macdonald in England and Tiemann and Gärtner in Germany have no other methods to propose.

By straining through cloth a known amount of water, and afterwards detaching the organisms held back by the cloth, upon a slide, where they could be approximately enumerated, the biologists working for the Massachusetts State Board of Health made a decided step in advance. Mr. A. L. Kean, working under my direction, sought to improve upon the cloth method by the use of a sand-filter, and counted by means of the examination of a thousandth part of the whole in a ruled cell holding one cubic millimeter. Still more recently I have myself constructed a counting chamber, so arranged that a cubic centimetre, or more, of water may be examined directly, or, in case the organisms are few, the entire mass of sand and organisms left by filtration of a known amount of water (usually 100cc.) can be evenly distributed on a glass plate, then viewed with a moderately high power, and the organisms studied and enumerated with considerable precision. A full account of the various methods, with results obtained by their use, will appear in a forthcoming report of the State Board of Health of Massachusetts. At present I will only state that this one consists, first, in the *concentration* (if necessary) of the organisms in a large amount of water into a small amount, so that they may be readily scrutinized. This is done by filtration through a short column of fine sand in a narrow-stemmed funnel, the sand being supported upon a platform of the finest wire-gauge cloth. To secure the second point (the *enumeration*), the sand and organisms are washed down by distilled water into a shallow chamber, ruled into squares, each one square millimeter in area. These are passed successively through the field of the microscope, and their contents observed or counted. I may quote a few results: —

	Per cubic centimetre.
Boston. (Cochituate. June 11)	12
Waltham. (Filter-basin. May 13)	4
Waltham. (Reservoir. May 13)	9

	Per cubic centimetre.
Waltham. (Tap. May 13)	12
Lawrence. (Tap)	23
Newton. (Filter basin)	12
Newton. (Reservoir)	1,602
Newton. (Tap)	23 to 5,565

From these figures it appears that a teaspoonful of drinking-water often contains from twelve to fifty microscopical microörganisms, and may sometimes contain thousands. Indeed, they often far outnumber the bacteria, as, for instance, in the Newton reservoir, where, with 1,602 microscopical, only 6 bacterial microörganisms were found in a cubic centimetre of water. In this connection I may mention a curious result, which was disclosed by an application of the method to the Newton water-supply. Water was drawn from the tap in the railway station at Newton Highlands every morning, excepting on Sunday. On Mondays the numbers were observed to be very high, reaching into the thousands per cubic centimetre, while during the rest of the week they barely reached hundreds. Inquiry disclosed the fact that on week days water is pumped from the filter-basin directly into the service-pipes. On Sundays the pumps are not run, and the pipes are filled from the reservoir. The reservoir water, however, is much less pure than that drawn directly from the filter-basin; and this fact became immediately and strikingly apparent by the examination of a sample collected early on Monday morning, before the pipes had been filled from the filter-basin.

It may fairly be claimed, I think, that we now possess a simple, convenient, and effective method for the enumeration and study of the microscopical microörganisms. There is no doubt that this is a step forward in the biological analysis of water, which must henceforward include microscopical as well as bacterial examinations.

As the result of his own studies upon drinking-waters, Cohn, in the paper already referred to, laid down certain generalizations that do not seem to have attracted the attention which, if true, they should have received. For example (*l. c.*, p. 113): "We may divide the organisms in drinking-water [wells] into three categories, which correspond to different degrees of purity of the water:—

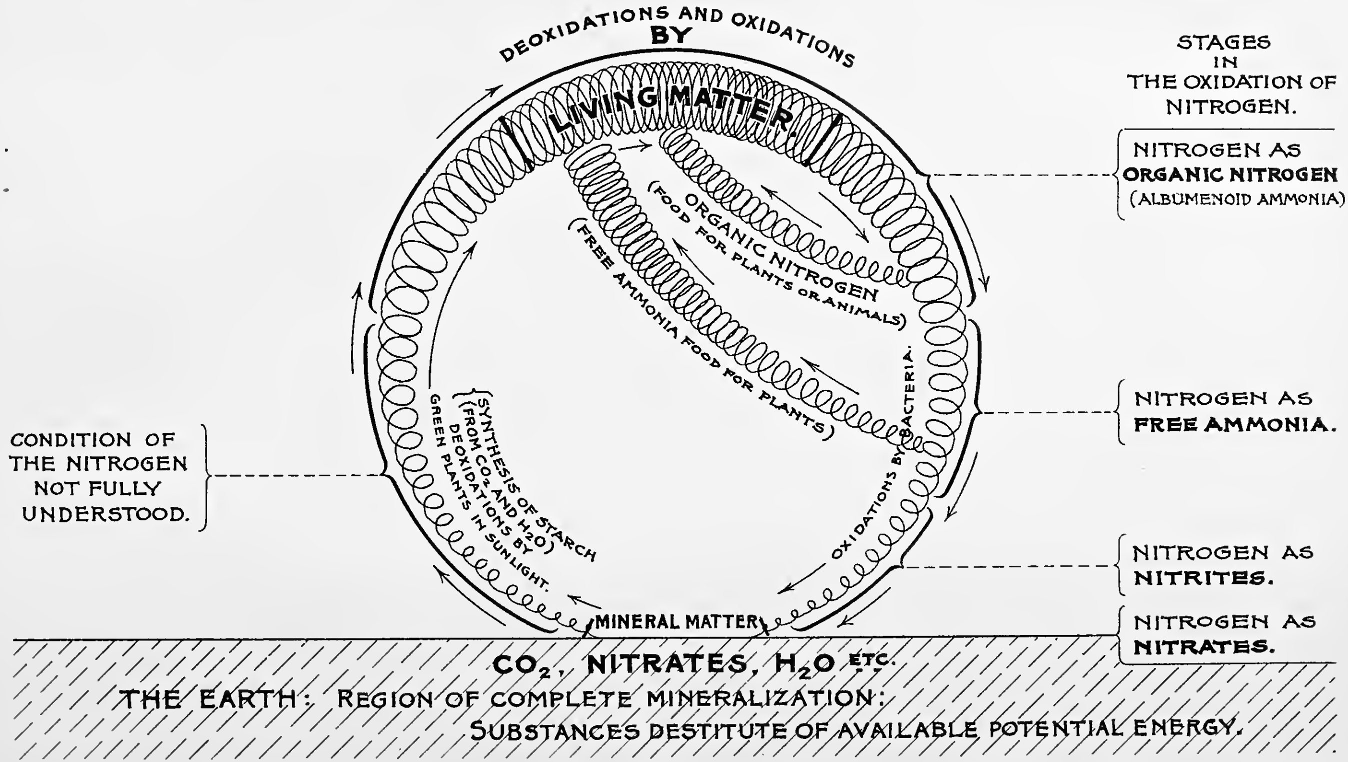
"1. Diatoms and green algæ indicate a water to which light has had access, and one poor in organic matter.

"2. Certain of the larger infusoria, especially the ciliated forms, feed on these algæ; while upon both the infusoria and the algæ, feed—

"3. Entomostracans, like Cyclops and the water-flea, worms, such as Naids and rotifers, and insect larvæ."

The presence of these last scavengers-in-chief Cohn does not regard as inconsistent with the purity of the water. He considers it to be the function of the rhizopods, carnivorous infusoria, rotifer vulgaris, mites, and the water-bears, to devour solid or undissolved bits of organic matter; and of the mouthless infusoria and the bacteria, to flourish upon dissolved organic matters. The latest

ORGANIC MATTER
IN SOME OF ITS
BIOLOGICAL AND CHEMICAL
RELATIONS.



EXPLANATION OF THE DIAGRAM.

The diagram on the opposite page is an attempt to show, in the simplest manner, and with special reference to water-analyses, some of the principal facts in the origin and fate of organic matter. In the long run, the history of organic matter is cyclical, and accordingly it has been marked out here upon a circle, springing from the earth and eventually returning to it. By stages of ever-increasing complexity, roughly indicated by the constantly closer and broader turns of the spirals, there are gradually built up from the inorganic matters of the earth and air, organic matters of constantly greater instability and larger potential energy, until, at the very top of the circle, living matter, the most "organic" of all matter, stands diametrically opposed to mineral or inorganic matter. This entire constructive phase (*anabolism*) is essentially a process of deoxidation, and is the special function of green (chlorophyll bearing) plants endowed with the energy of sunlight. At some stages, however, and especially near the top, there is reason to believe that the animals and the colorless plants also freely effect deoxidations and the construction of the higher forms of organic matter.

After death the organic matters of the recently living plant or animal are returned, step by step, to the earthy condition (the various acts of decomposition, taken as a whole, being sometimes described as *katabolism*) by processes of oxidation effected chiefly by the bacteria, which are therefore oxidizing agents *par excellence*. These organisms find their power and therefore their reward, in the energy which they derive from the oxidation of relatively unstable compounds to those more stable, and poorer in potential energy.

The brackets in the diagram approach too closely one to another. There are possibly important stages between, for example, "free ammonia" and "nitrites," which chemists have not yet fully apprehended.

It is probably very seldom that any particular portion of matter proceeds over the exact route indicated by the diagram. There are innumerable "short cuts" or "reverses," by which lately dead organic matter is rebuilt directly into living matter; or by which free ammonia or nitrites are fed upon by living plants. Such short circuiting is the rule, for example, in the feeding of the carnivora which devour animals lately killed, and composed largely of organic nitrogen. The upper of the included spirals in the diagram is meant to show such a "short circuit." Another, and highly instructive case is that referred to by Prof. Drown (p. 57), in which the living oscillaria in Jamaica Pond completely removed the free ammonia present. This is represented by the lower (and longer) of the included spirals. (See also p. 56.)

With this diagram in hand, it is hoped that the interpretation of the results of modern water-analyses will be greatly facilitated, even for those previously unfamiliar with the technical terms.

German work upon this subject (*Untersuchung des Wassers*, Tiemann und Gärtner, 1889) does scarcely more in this direction than quote the above remarks of Cohn, and adds, "At the present time more stress is to be laid upon the quantity than upon the quality of the microscopic organisms."

In my opinion, it is in working out precisely such inter-relations and interdependencies of the microörganisms as are suggested by Cohn that we are now making real progress, and are likely to advance in the near future. It is self-evident that such laws, if firmly established, must become of the greatest scientific and practical value to all concerned in the use and the supply of wholesome drinking water.

It is necessary, however, to go one step further. The protest of Dr. Hassal, quoted above, against the use by chemists and others of the indefinite term "organic matter," has lost none of its force by the lapse of time. On the contrary, it is less defensible than ever, and the time is gone by for students of water supplies to be satisfied if, in reports of chemical analyses, they find "the different kinds of organic matter, vegetable and animal, living and dead, all lumped together." Recent investigations show that such terms as "nitrates," "nitrites," and "free ammonia," have a definite meaning in important biological conditions, and some of these are suggested by the diagram at the end of this paper.

Finally, it is not too much to affirm that, if it ever existed, the time is gone by when either a microscopical examination alone, or a bacterial examination alone, will suffice to base a professional or expert opinion of water upon. And furthermore, it is becoming clearer every day that an opinion of a water based upon chemical observation alone (and, above all, upon a single analysis), is no longer a complete scientific opinion. A water-analysis henceforwards must be a threefold analysis, viz., chemical, bacterial, and microscopical; and even then the conditions of its origin and of the neighborhood of its source must be included as a factor of equal importance. The standard of water-analysis has of late unquestionably risen, and reports of "water-analyses," if they are to fulfil the conditions imposed by the most recent progress, must include three different examinations, as follows: —

EXAMINATIONS REQUIRED FOR A COMPLETE WATER-ANALYSIS.

I. Environmental, *i.e.*, a more or less complete study of the source of the water, together with observations of the surroundings, and investigation of specimens unquestionably normal, from the vicinity.

II. Chemical, *i.e.*, the usual chemical analysis, with special attention, however, to the state of the nitrogen present.

III. Biological, *i.e.* (1), *Microscopical*, viz., a determination of the number, the species, and, as far as possible, the conditions of the larger microörganisms present; as well as of the masses of *débris*, etc.

(2) *Bacterial*, viz., a determination of the number, and, as far as possible, of the species of the living bacterial organisms present.

DISCUSSION.

Remarks of Professor Drown.

The President called upon Prof. Thomas M. Drown to open the discussion.

Prof. Drown. — I may, perhaps, supplement Professor Sedgwick's paper by an account of some experiments I have recently made to determine what kinds of nitrogenous food algæ are capable of assimilating, and I have selected for this purpose the four substances which Professor Sedgwick has placed on his chart, namely, organic nitrogen, or albuminoid ammonia, free ammonia, and the nitrites and nitrates. From a sanitary standpoint it is the changes of the nitrogenous substances in water which chiefly interest us; and those changes are progressive in the direction already given, that is, from organic nitrogen through ammonia and nitrites to the complete mineralization of the nitrogen in nitrates. Now, leaving out of consideration the causation of disease by specific germs, we may say that we associate unwholesomeness with the idea of decomposition. Decay going on in water, in large amount, generally gives rise to offensive odor and tastes, which would cause one to reject the water without any professional opinion as to its wholesomeness. And there is positive evidence to enable us to say that nitrogenous substances, undergoing decomposition taken into the system are capable of causing sickness.

The presence of algæ in drinking-water is generally considered unneccessary, very often they are unsightly, and the cause frequently of unpleasant odor and tastes. And yet there is a good word to be said for the algæ, or, at least, for some of them. My experiments go to show that the algæ may be nourished by organic nitrogen, by ammonia, and by nitrites and nitrates. The first three mentioned are substances which are capable of undergoing further change. In some way the unwholesomeness of water is connected with this change, and I have been disposed to formulate this fact in this way: *The state of change is the state of danger.*

The last condition, that of nitrates, is incapable of further change or oxidation, but until we get to this stage there is change going on. Now, if the algæ will take up the organic nitrogen, the ammonia, and the nitrites, they will remove from the water substances capable of undergoing change, and in so far I cannot help thinking that they are doing a good work.

My experiments were made in this way: In each case I took two jars — battery jars are very convenient for the purpose — and put into both of them water containing, in solution, some one of the above-mentioned substances, and into one, only, some growing water-plant. The solution was analyzed at the beginning of the experiment, and the jars were then exposed to sunlight for several weeks, analyses of the water in the two jars being made at intervals of a few days. For organic nitrogen I used a solution of pepsin, a substance which decomposes very rapidly in solution, developing ammonia freely. In this case the jar without the alga showed very promptly a large amount of ammonia, and there was also a disagreeable odor after a short time. In the other jar containing the alga there was no odor, and free ammonia was not formed. It is impossible to say definitely in this case whether the plant fed directly on the pepsin or whether ammonia was formed and appropriated immediately, or that there was no accumulation of ammonia.

In another series of experiments an ammoniacal salt — ammonium chloride — was used. This was quickly absorbed by the plant, while the water in the companion experiment, with the same amount of ammonia, showed no change on standing. In still another series, sewage was added to the water in the jars, and in one — that containing the growing plant — the evidences of pollution disappeared in a short time, while the other retained all the characters of dilute sewage. In all cases the plant grew rapidly and seemed very healthy. The nitrites, in another series of similar experiments, were also removed from the solution by the growing plant. Now, I cannot help thinking that the algæ do a good work in taking up these products of decomposition, and thus preventing them from completing the changes which they would otherwise naturally undergo. The general impression as to the nature of the self-purification of rivers and surface-waters generally, is, I think, that the organic matter is ultimately completely oxidized, and that the green water-plants aid in this process by giving off oxygen as one of the products of their life. This process of oxidation certainly does go on, but it seems to me that with abundant plant-life in the water the probabilities are that the greater part of the introgenous matter will be absorbed before it is oxidized.

But it will be said, "Does not this vegetable growth ultimately die and give in its turn the same products of decomposition?" That is certainly the case with all living matter, but when a body of water is in a normal condition there ought to be enough new life arising out of the decomposition of the old to prevent the products of decomposition from accumulating. A "stagnant" pond is one in which decay gets ahead of growth. Here comes in, too, the interplay of animal and vegetable life in the water. The animal forms consume the vegetable life, and the products of the animal decomposition are absorbed by new plant life. In this latter case the service which the algæ do as in keeping the water wholesome is much greater than when they simply consume the products of the decomposition of other plants. Animal decomposition is what gives sewage its dangerous character. If the algæ are present in a sewage-polluted pond or stream in sufficient amount they may keep the water in good condition, or at least, prevent it from becoming foul. We have a confirmation of these experiments on the large scale in ponds which we know receive sewage. Horn pond in Woburn, as is well known, is a badly polluted pond, and the water is generally high in ammonia. But, occasionally, during the warm weather, when the plant life is abundant the ammonia is entirely absent.

During the past few months Jamaica pond, Boston, has contained an excessive amount of the alga *Oscillaria*. The water has been quite thick with it, and the pond had a reddish tint from this plant. Although the water was thus rendered unsightly and unpalatable, yet the ammonia, which is usually very high in this water in the winter and spring months, disappeared entirely in April and May. It is true that there are some algæ, — particularly those belonging to the blue-green variety, — which grow, under favorable conditions, with such great rapidity, forming lily-like masses, that they become a nuisance in themselves. When these masses are driven by the wind to one side of a pond, they may decompose on the shore-line and communicate to the water the characteristic "pig-pen" odor. Again, there is good reason to believe that many algæ have unpleasant odors and tastes while in a healthy living condition, and communicate their odors and tastes to the water. Still, we may affirm, as a broad statement, that the

ability which growing water-plants possess to absorb decomposing matters and the intermediate products of decomposition, renders their presence in surface waters generally advantageous. An ideal condition of affairs would be that in which we made use of the algæ to purify a water, and then filtered them out of the water before drinking it.

At the beginning of my remarks I mentioned the *nitrates* as food upon which water-plants might live. This was proved by experiments like those already described. But in this case we cannot look upon the algæ as purifying the water. Indeed, the contrary is the case. Nitrates represent the last condition of oxidation of nitrogen when it is entirely in the mineral form, with all trace of its organic origin lost. Now, when algæ live on nitrates they convert some of this completely oxidized nitrogen into organic nitrogen, which must go through the series of changes which we have described, until it again reaches the condition of nitrates; unless, indeed, some of the intermediate products are absorbed by new growth. You are all familiar with the rapid growth of organisms when a ground-water, high in nitrates, is exposed to light and air in an open reservoir. The water as it comes from the well is, as we will suppose, in perfect condition for domestic use, — free from all trace of organic matter; and in a few days we have it swarming with vegetable life, often associated with unpleasant tastes and odors. In such case the growth of algæ serves no useful purpose, but is the cause of a direct and decided deterioration of the water.

Remarks of Frederick P. Stearns.

The President then called upon Mr. Frederick P. Stearns, chief engineer of the Massachusetts State Board of Health, to continue the discussion.

Mr. Stearns. — When I was asked by the secretary if I would say something on this subject, I did not know what I could say that would interest you; so I arranged to exhibit to you a few samples of water, some of them containing algæ.

One of these two samples is a ground-water, just as taken from the ground, the other is the same water after storage in an open reservoir about a month. There is a slight difference in the appearance of these waters, but I do not think you can detect it from where you sit. I expected to find this sample from the open reservoir grass green, as it was about four days ago. The superintendent who sent this water wrote me that there had been a remarkable change in the appearance of the water, the green growth having settled to the bottom of the reservoir. The reservoir from which this water was taken was thoroughly cleaned about a month since, and filled with water direct from the wells; and the gates at the reservoir were then shut. In less than a week the water in the reservoir was filled with this green growth, which remained in it until a few days since, when most of it disappeared.

The third sample represents the Fall River water, drawn from a tap in this hall, which ranks high in appearance among the surface-waters of the State. You will observe, however, that it compares unfavorably with the ground-water in the first sample.

This sample represents what we term imperfectly filtered water. Water was originally supplied to these works directly, by gravity, from a storage reservoir; but, the water being unsatisfactory, a trench was dug when the reservoir was low, near the high-water line. In the bottom of the trench a culvert, with open

joints, was placed, and the trench was refilled. When the reservoir is full the water stands directly over some portions of the culvert, or filter-gallery, as it may be called, and filters continuously through a comparatively thin layer of earth. The result of this filtration is, that not much of the organic matter is removed, and an organism called crenothrix develops in great abundance in the water. It is a peculiarity of this organism that it becomes incrusted with iron. The flocculent, rust-colored sediment in the bottom of this bottle is crenothrix, with this incrustation. During two or three months in summer this water, when used for washing, leaves iron stains on the clothes. I have here another sample, blown from the dead end at a hydrant on the same works, which contains a large accumulation of crenothrix and iron. There are four supplies in the State where the water is very imperfectly filtered, and in each case there is a growth of crenothrix.

With these facts as a basis, the prediction may be made with a fair degree of certainty, that if you attempt to filter water continuously through a thin layer of earth, and without any means of cleaning the filter, you will be troubled with a a growth of crenothrix.

These two bottles contain growths of algæ, which develop mostly in the hot weather of summer. Although one of the waters is light colored, and the other much darker, the growths in them affect the waters in about the same way, as I will explain by these diagrams on the walls, which show the amount of albuminoid ammonia found by monthly chemical examinations of the water from June, 1887, to June, 1889.

The albuminoid ammonia of these particular waters represents approximately the variation in the quantity of algæ in the water. In these two diagrams you will observe that the line runs high in summer, in 1887 and 1888, reaching the highest point in August of each year, when it is about three times as high as during the winter. The upward tendency of the lines at the present time indicates that there may be another high point next August. There is one other water in the State which acts in almost precisely the same way as the two represented by these diagrams.

I will now call your attention to this sample of Jamaica pond water, which has been already spoken of. I presume you can see that it is very different in appearance from the other waters. This other bottle, containing a chocolate-colored mixture, was ladled up near the shore of Jamaica pond, and contains an accumulation of the particular organism found in great abundance in the water of this pond. I will now refer you to the third diagram, which represents the albuminoid ammonia found in the water from this pond. At the present time you will observe that it is extremely high, and that the rise began at the beginning of last autumn, and continued through the winter. The previous winter no marked rise occurred. The conditions during the winter before are not known, as the State Board of Health did not begin to examine water supplies until the following June. The marked drop in the line from June to July is a strong indication that the line was much higher before June.

These diagrams may prove instructive in two ways. First, they show that the waters of storage reservoirs and ponds in the State can be divided to some extent into classes which undergo similar changes during the year, and this classification furnishes a starting-point for determining the cause of these changes, and why they occur in certain waters and not in others. Second, they show how little

will be known of the character of a water in some cases from a single analysis. If a new supply is to be taken from a pond, or from an existing artificial reservoir, it would be desirable to have analyses taken frequently for a year, to determine if any changes took place which corresponded with changes taking place in the waters which give the most trouble.

Remarks of Desmond FitzGerald.

The President then called upon Desmond FitzGerald, Resident Engineer and Superintendent of the Western Division of the Boston Water Works.

Mr. FitzGerald. — I had not arranged to say anything on this subject, although, of course, it is an extremely interesting one to us all. When I first looked at these diagrams, and heard Professor Sedgwick begin his remarks, I thought I knew something about this matter, but now, after having heard what has been said by these gentlemen who have addressed us, I have come to the conclusion that I know nothing about it. There are several practical questions that come up in this connection which may be said to go hand in hand with these examinations, chemical, biological, etc. One question I want to ask is, Whether it is possible by chemical analysis to determine the loss in the water, in this first step, if it may be called a step, that is, the deoxidation process, or, in other words, the building up from the mineral into the vegetable; whether the chemical analysis is sufficiently delicate to determine that there is an absolute loss in the change from the mineral to the vegetable?

Professor Sedgwick. — It is.

Mr. FitzGerald. — I understand it is so. Then comes the practical question, Whether that loss is one which will be beneficial to the water consumers or not? If the decomposition of the algæ is a very slow one, I am at a loss to understand why, when we filter comparatively pure water through a sponge, for instance, at the end of twenty-four hours there will be such a mass of decomposing matter as to be very offensive. That was partly answered by Professor Drown's remark to the effect that the offensive smell might come as well from the processes of growth as from decay, which was a new idea to me.

Mr. Stearns' remarks have shown some interesting progress. It will be remembered, perhaps, by members of the Association that when this matter first started I took a somewhat favorable view of the probable results which would be obtained, and I think those have now begun to show themselves in these comparisons and classifications. But, of course, the matter is still in its infancy, for it is a very big subject, and we cannot expect everything at once. It seems to me these gentlemen are all giving intelligent study to it, and will bring us excellent results in the future.

When our water-supply in the city of Boston was attacked a few years ago, we ran all the water from Farm pond down into the Chestnut-hill reservoir. It was full of albuminoid ammonia, and was very offensive, so offensive that a bath in Boston water was really objectionable. I kept the water stored there in Chestnut-hill reservoir about a foot above high-water mark for several months, and it took almost all that time for the water to purify itself. And the question which it occurred me to ask in connection with that was, Whether the old idea that oxygen from the air had anything to do with the purification had been given

up? That was partly answered by Professor Sedgwick's remark that the effect of the bacteria was chiefly one of oxidation. Of course, if the bacteria purified the water, the exposure to the air had nothing to do with the process, I suppose. As matter of fact, the water did purify itself perfectly under the ice, so that very early in the spring it was as good as any water we ever delivered to the city. But a short time before the ice broke up the water was so bad that the effect of simply opening the gate was noticed by almost everybody in the city. I opened the gate one night on purpose to make the experiment in the cause of science. [Laughter.]

Professor Sedgwick's remark, that there is almost always a day of reckoning, seems to me particularly applicable to the case of Newton. You remember that not so very long ago, my friend Mr. Noyes, of Newton, was taking a very high position in regard to the quality of his Newton water in comparison with our Boston water. But gradually the net is drawing around him, and when Professor Sedgwick gave his figures showing that there were only 12,000 of these living creatures per litre in the Boston water, and from one to five millions of them in the Newton water, my spirits rose. (Laughter.) I think while Newton may possibly sell some of her water to Boston, it may be, perhaps, because the people there are very fond of soup. (Laughter.) I dare say I have gained a point now on my friend from Newton, if I did lose one a year ago. I am sorry I haven't something of more value to add to this discussion. I may say we have been examining the Boston waters from different sources under the microscope, and it is a matter of a great deal of interest to me, and surprising to see the difference in the water at different times and from different reservoirs. We are preparing on the Boston works to do this a little more scientifically than we have been doing, and we are going to start, perhaps, something which is in the nature of a biological laboratory, where we can make systematic records in connection with the chemical examinations, in addition to what the State Board of Health is doing, and perhaps carry it out a little more in detail. Mr. Forbes has been making a good many examinations of Brookline water, and I have no doubt he can add to this discussion, especially to the microscopical part of it.

In regard to the removing of the algæ, what I am particularly interested in now is to ascertain whether it will be an actual benefit to the water to remove from it the algæ in their first forms of growth; and it has seemed to me, without going into it scientifically, that it would be a benefit to the water. I know if we pass a large quantity of water through a sponge, we get certainly a very nasty mess as a result, and it seems to me that is the thing we want to remove from the water. (Applause.)

GENERAL DISCUSSION.

Mr. Noyes. — I have been trying to think of a reason, other than the reason Professor Sedgwick assigned, for there being so great increase in the number of bacteria in the Newton water on Sunday. I can only account for it in one other way, and that is this: You know Newton is entirely a residential city, and the business men are at home on Sundays, and it must be because there is no water drunk there that day. [Laughter.] I would like to ask Mr. Stearns one question with reference to that class of waters of which he showed a sample which he said was drawn from a dead-end, and that is, whether its appearance

was not to some extent due to the iron in the pipe, and not entirely due to the death and decomposition of the growth that he mentioned?

Mr. Stearns. — I think the iron does not come from the pipe.

Mr. Noyes. — But is entirely due to the growth you mentioned?

Mr. Stearns. — It may not be entirely due to the iron in the water, but I think it is chiefly due to this iron and the growth which collects it.

Mr. Noyes. — That is, the presence of the iron fertilizes the growth, or causes it?

Mr. Stearns. — It is associated with the growth, I do not know how. The water also contains a high percentage of free ammonia, and that may have something to do with it.

Mr. Allis. — I would like to ask Mr. Stearns if the iron is from the pipes or the water itself. Is the water itself carrying the iron out of the pond? Is there iron in the water?

Mr. Stearns. — I go mainly by what I have read about it. I don't know much about it from my own investigations, but I understand that water in going through the ground, particularly if the water contains a good deal of organic matter, will dissolve iron out of the ground. There are some tanks in Lawrence, where the State board is testing the filtration of sewage, and experiments in filtering through a tank of garden soil gives a red effluent, containing iron about the color of this sample. When the water comes from the tank it is perfectly clear before it is exposed to the air, but after it is exposed to the air the iron oxidizes and turns the water red.

Mr. FitzGerald. — I should like to ascertain from these gentlemen who have made a special study of this matter, if the very addition of this last process of that circle, the mineralization of the water, does not, in effect, make the starting-point for the new growth? There is something in the way in which waters act, practically, that suggests that to my mind. The water in the main may not be at all like that which you send in from the reservoir, and I have had occasion to examine the contents of some very large pipes, and I have been astounded to find the quantity of growth in them. I have seen in a very large pipe the sponge so thick between the tubercles that it was one mass of living matter. And, then, the analyses of the water from the pipes, the tap water, shows the same difference; it changes in the same ratio. Now, that growth, if I understand this process correctly, that growth is at the summit of this profile, that is, the living matter has got up to its highest state of nitrogen, organic nitrogen, and it must have had an excess of mineralization to have built itself up under these unfavorable conditions on the inside of the pipe. Before that begins to decay, which, of course, will make the water very offensive to the town or city, it must have had this food to have built itself up with. Then we have a decay again, and then it passes into this state of mineralization. Now, the question is, whether the water going from the reservoir into the pipes does not contain such an excess of mineralization as to start anew the very circle of growth? It seems to me that is a subject I should like to have some light upon.

Professor Sedgwick. — I should say it is not exactly that, but rather, perhaps, this: of course this diagram is the reduction to the lowest terms of the whole story, and it also shows the longest direct route which organic matter can take. Professor Drown has told you how there may be cross-links, as it were; how free

ammonia, for instance, instead of nitrates, may become food for green plants; how *Spirogyra*, which is a fine green alga often seen in waters, may take the free ammonia at this point, and may not allow it to get down here at all, but may seize it and build it right up into living *Spirogyra* by a shorter cut than usual. And we have reason to believe that the same thing may happen from the nitrite stage also. These algæ only take nitrates when they cannot get anything better. They are going to feed on organic nitrogen if they can; they are going to feed on free ammonia when they cannot get that; and they are not going to take nitrates except in the hardest times. This diagram represents the organic matter, so to speak, going over the most direct routes; but there are many short cuts and reverses, so that it may be a very long time before any particular particle of matter gets over the entire route.

Now, as to the sponge. It is not always green, and it does not absolutely need the sunlight, but it does in this case need something which has been green and has had the sunlight, or else has fed upon such things. In other words, it depends in the long run upon vegetable food. Now, as it lives in conduits and such places, there are always coming in green organisms which have been in the sunlight in the reservoir, and which have, perhaps, recently died, or which may be still alive, and the sponge takes them, — now dead organic matter merely, or even if living, — and builds them right up into *Spongilla*, one of the highest forms of organic matter (though one of the lowest forms of life). But, so far as we know, the sponge is not able to take nitrates and build them up into anything. That is the exclusive province of the green plants in the sunlight. They alone stand between us and destruction. If the green plants were exterminated, and if eternal night came on, we, in common with all other animals, would perish, because in the long run we are dependent on plants and the sun. So with the sponge. It is utterly powerless unless there come to it organic matter prepared by green plants, or, as we have called it, ready-made food, which may be either its nearest neighbors on the diagram, *viz.:* living animals and plants, or by a somewhat longer "short cut," highly energized, though dead, organic matter.

Mr. FitzGerald. — That answers the question, and it seems to me it tends to confirm exactly what I think showed itself to my mind practically, by some experiments I have been making, and that is, that *it is desirable to remove the algæ from the water before sending it into the mains.*

Mr. Chace. — I should like to ask Professor Sedgwick one question. I understood him to speak of bacteria as fungi. There have been some books published in which they have been spoken of somewhat doubtfully as algæ. I would like to ask if it has been definitely settled they are algæ.

Professor Sedgwick. — To all intents and purposes they are fungi, but some of them are so near to some of the algæ that it is still a matter of doubt to some whether they should be called algæ or not. Practically, we may regard them as fungi without any question. The moment they become algæ and take on chlorophyll, they move from the right hand side of that diagram to the left. But as 999 out of 1,000 of them are undoubtedly destitute of green coloring matter, they are for the present at any rate, and always practically, to be regarded as fungi.

Mr. Glover. — I would like to ask Professor Sedgwick if there is anything which will remove these microbes from the water. If his statement with regard

to our water is correct, and there is any such thing, I want to get one before I go back home. (Laughter.)

Professor SEDGWICK. — There are such filters. One hundred feet of fine sand will do it, and probably do it effectually. And there are some porcelain filters which will do it for a time at least. The ordinary filters are simply strainers. But there are a few which certainly do, at least for a time. How long they will continue to do so is a question. The microscopical forms are easily taken out, and still larger forms are still more easily taken out, but I understood the question to refer to the microbes, which are the bacteria. The microscopical forms are comparatively very large, but the bacterial are very small, and will go through almost any hole.

OBITUARY.

W. C. BOYCE, — Civil Engineer, Worcester, Mass., died July 15, 1889, aged 37 years 5 days. Joined this Association June 17, 1887.

NEW ENGLAND WATER WORKS ASSOCIATION.

ORGANIZED 1882.

Vol. IV. December, 1889. No. 2.

This Association, as a Body, is not responsible for statements or opinions of any of its members.

QUARTERLY MEETING.

YOUNG'S HOTEL, BOSTON, MASS., Dec. 11, 1889.

About eighty members and guests of the Association assembled on this date at Young's Hotel, in response to a call issued for the regular quarterly meeting. The names of those present, as far as the Secretary has been able to obtain them, are as follows: —

LIST OF MEMBERS ATTENDING MEETING OF DEC. 11, 1889.

F. A. Andrews, of Nashua, N. H.
S. M. Allen, of Malden, Mass.
C. H. Baldwin, of Boston, Mass.
W. H. Barney, of Milford, Mass.
Everett Barns, of Westerly, R. I.
J. E. Beals, of Middleboro', Mass.
W. R. Billings, of Taunton, Mass.
G. H. Bishop, of Middletown, Conn.
Dexter Brackett, of Boston, Mass.
J. H. Brown, of Charlestown, Mass.
E. W. Cate, of Newton, Mass.
G. F. Chace, of Taunton, Mass.
H. W. Conant, of Gardner, Mass.
R. C. P. Coggeshall, of New Bedford, Mass.
B. I. Cook, of Woonsocket, R. I.
F. H. Crandall, of Burlington, Vt.
Lucas Cushing, of Boston, Mass.
Edwin Darling, of Pawtucket, R. I.
A. B. Drake, of New Bedford, Mass.
H. L. Eaton, of Somerville, Mass.
G. E. Evans, of Lowell, Mass.
Desmond FitzGerald, of Boston, Mass.
F. F. Forbes, of Brookline, Mass.
J. R. Freeman, of Boston, Mass.
F. L. Fuller, of Boston, Mass.
A. S. Glover, of Newton, Mass.
J. A. Gould, of Newton, Mass.
E. H. Gowing, of Reading, Mass.
R. A. Hale, of Lawrence, Mass.
F. E. Hall, of Quincy, Mass.
J. L. Harrington, of Cambridge, Mass.
D. A. Harris, of New Britain, Conn.
J. C. Haskell, of Lynn, Mass.
W. M. Hawes, of Fall River, Mass.
Patrick Kieran, of Fall River, Mass.
G. A. Kimball, of Boston, Mass.
T. C. Lovell, of Fitchburg, Mass.
Hiram Nevons, of Cambridge, Mass.
J. H. Perkins, of Watertown, Mass.
G. J. Ries, of East Weymouth, Mass.
W. H. Richards, of New London, Conn.
W. W. Robertson, of Fall River, Mass.
Henry Rogers, of Salem, Mass.
J. H. Shedd, of Providence, R. I.
S. F. Smith, of Grafton, Mass.
G. A. Stacy, of Marlboro', Mass.
F. P. Stearns, of Boston, Mass.
M. M. Tidd, of Boston, Mass.
C. H. Truesdell, of North Grosvenordale, Conn.
G. P. Westcott, of Portland, Me.
W. P. Whittemore, of North Attleboro', Mass.
G. E. Winslow, of Waltham, Mass.
M. F. Wright, of Lowell, Mass.
E. R. Jones, of Boston, Mass.

And representatives from —

American Frost Meter Company.
H. R. Beecher Manufacturing Company, Lowell, Mass.
H. R. Worthington & Co.
Chadwick Lead Company.
Hersey Meter Company.
Holyoke Hydrant and Iron Company.
George Ross Company, of Troy, N. Y.
Union Water Meter Company.
Walworth Manufacturing Company.
Water Waste Prevention Company.
Whittier Machine Company.
And the "Engineering and Building Record."

For an hour or two before one o'clock the members assembled in the rooms provided for their use, and employed their time in social converse till lunch was announced, when they proceeded to the dining-room. At two o'clock, lunch being over and cigars lighted, President Brackett rapped to order, and called upon the Secretary, who presented the following-named list of applicants for membership in the Association: —

FOR ACTIVE RESIDENT MEMBERSHIP.

1. Elmer E. Farnham, Superintendent, Sharon, Mass.
2. Charles F. Parks, Civil Engineer, 89 State st., Boston, Mass.
3. William Wheeler, Civil Engineer, 89 State st., Boston, Mass.
4. John W. Ellis, Water Commissioner, Woonsocket, R. I.
5. John C. Haskell, Superintendent, Lynn, Mass.
6. W. H. Vaughn, Superintendent, Wellesley Hills, Mass.

FOR NON-RESIDENT ACTIVE MEMBERSHIP.

7. Edward M. Boggs, Hydraulic Engineer, San Bernardino, Cal.
8. William E. Davis, Superintendent, Sherburne, N. Y.
9. J. E. Denton, Prof. Experimental Mechanics, Stevens Institute, Hoboken, N. J.
10. E. P. Foster, Superintendent, Santa Anna Water Co., San Buenaventura, Ventura Co., Cal.
11. Harry G. Koch, Superintendent, Castle Creek Water Co., Aspen, Col.
12. Samuel B. Leach, Civil Engineer, North Tarrytown, N. Y.
13. C. H. Tompkins, Jr., Engineer and Manager, Idaho Mining and Irrigation Co., Boise City, Idaho Territory.

The Secretary stated that the applicants were all approved by the Executive Committee, and it was voted that the Secretary cast the ballot of the Association for the list as read. This having been done the President announced the gentlemen voted for as duly elected members of the Association.

The Secretary then announced the following changes in addresses of members: —

Melvin C. French, Superintendent, Box 165, So. Braintree, Mass.
Hiland C. Hitchcock, 99 Blossom st., Fitchburg, Mass.

There being no further business, President Brackett opened the discussion of the afternoon with the following remarks: —

The President. — *Gentlemen of the New England Water Works Association*, — The attendance here to-day assures me that you are still interested in the affairs of the Association, and also encourages me in the belief that you are all ready and willing to assist in making the meetings of the coming year as interesting and instructive as those of the past have been. For the honor which you have conferred upon me by placing me in my present position, I desire to thank the Association, and in fulfilling the duties of the office I shall assume that you all agree with the opinion of one of your former presidents, expressed in the statement that "it is water works and not oratory in which we are interested." One of the objects of the Association is the maintenance of a spirit of fraternity among the members by social intercourse and by the discussion of subjects relating to water supply; and in this spirit we should all be willing to do what we can to further the ends of the Association. The little things, the details which make up the bulk of our daily work, are often of great value, and the short papers which were presented during the last year, at one or two of the meetings, were of much interest. There was but a very small proportion of our members, however, who furnished us with those papers. It is proposed, at the next meeting in January, to continue this plan, and I wish to have as many as are willing volunteer to-day to present, at the next meeting, short papers, not to exceed five minutes in length, connected with the question of water supply. Who is willing to volunteer?

(Messrs. Richards, Coggeshall, Tidd, Nevons, Holden, Kimball, Eaton, Darling, Harrington, Winslow, Rogers, Hawes, Welch, and Hall either volunteered or were designated by the President.)

The President. — Since our annual meeting at Fall River there has been another gathering of the Association which was participated in by a number of those here present. I wish that all might have been there, and in order that those who were not with us may obtain some little idea of what occurred at our fall meeting I will now call on Vice-President Hawes, of Fall River, who will give you a report of our proceedings on that occasion. (Applause and laughter.)

FALL MEETING, SEPTEMBER, 1889.

Mr. Hawes. — It is a little too bad to disturb me just now, for I was 'most asleep. (Laughter.) I think considerable of that excursion. "I came, I saw, I conquered." (Laughter.) We went, we saw it, and we are mighty glad of it, — those who did go. (Laughter.) On the morning of the 29th of September — Saturday — we left Boston, and we had a very beautiful ride up to the Pemigewasset House, where we took dinner, as good as we could get (laughter); and then we went on to the Crawford House, where we arrived about half-past four or five o'clock, meeting with a very cordial reception, and being provided with a mighty good supper; and we were all ready for it, too. (Laughter.) The next

day was a beautiful day. The weather had been cold, and the highest mountain-tops were all covered with snow; and it was a strange and beautiful sight to most of us. We went up Mt. Willard, had a little snowballing, and a fine view. In the afternoon different parties wandered off to different places, and saw all there was to be seen. Some of the party started in the morning and went up to the summit of Mt. Washington and got "friz up." (Laughter.) The locomotive froze up while they were there, and they had to wait for it to be thawed out before they could come back (laughter); and they had a very cool time. We had a very pleasant gathering in the parlors of the Crawford House on Saturday and Sunday evenings, and a good sing.

On Monday morning about nine o'clock we left Crawford's and came down through the Notch to North Conway. The mountain scenery never looked better than it did then. Most of us who have been to the mountains have been in the summer, and have seen them in their dress of dark, cool green; but this day they were blazing in the brilliant glory of autumnal tints which illuminated the hill-sides, while the mountain summits were capped with the glistening white snow. We had impressed in our memories scenes which have made this tedious, bitter, cold, raw winter weather through which we are now passing seem bright to us. (Laughter.) We had our own train, our own private car, and our own water-boy, too. (Laughter.) I see you are inclined to laugh, but that is where the laugh comes in for those who were there. There were about sixty or seventy in the car, and we had a jolly good time. If there was anybody who went on that excursion who didn't have a good time, I would like to have him step outside and take it right out now; I will settle with him alone. (Laughter.) It was one of the pleasantest meetings that we ever had, one of the pleasantest of our field-day meetings, and it left a beautiful impression on the minds of both men and women, and I may add children, also. (Laughter.) I hope we shall be able to go again, and when we do go, you who couldn't go this time, hearing such favorable reports, I hope will be able to join us. I don't know that there is any more I can say, except that we all got home sober, as far as we could see (laughter), in a drenching rain. There were water works enough when we got home, you can bet on that. (Laughter and applause.)

At the conclusion of Mr. Hawes' remarks the President introduced Mr. Freeman, who read a paper entitled "Experiments and Practical Tables Relating to the Discharge of Fire Streams and the Loss of Pressure and Friction in Hose."

Mr. Freeman's paper was listened to with great interest, and at its conclusion was discussed by Messrs. Tidd, Jones, Brackett, Haskell, Shedd, Hawes, and Winslow.

[The paper and the accompanying discussion will appear in a future number of The Journal.]

At the conclusion of this discussion, upon motion of Mr. Hawes, the Association adjourned.

PAPERS READ AND DISCUSSED AT THE CONVENTION, HELD AT FALL RIVER, MASS., JUNE, 1889.

WATER-WORKS RECORDS.

BY

ALBERT S. GLOVER, Water Registrar, Newton, Mass.

It has often seemed strange to me that among the many subjects written upon and considered at our Water Association meetings, this of water-works records has never been discussed. With the exception of the able and valuable paper upon the desirability of a uniformity in the preparation and publication of water department reports, which was presented to our Association by Messrs. Billings and Coggeshall, in 1885, I know of no allusion to the matter. The importance of the question precludes, of course, the theory that it has been neglected through a lack of interest in it, and I think it can only be that the magnitude of the subject has acted as a discouragement to those attempting to write about it. I may possibly be inclined the more to this opinion from a slight study of the matter, since I was informed by our worthy secretary that I had been drafted to supply a paper upon this subject as a substitute for another expected from one of our members, who, fortunately for himself but unfortunately for you, has deserted us for the Engineer's Excursion abroad.

WATER-WORKS RECORDS.

This subject has a very wide range; it would include, of course, the records of systems of all kinds and descriptions; those deriving a supply from running streams, ponds, lakes, or wells; those sufficiently fortunate to be supplied by gravity, as well as those compelled by necessity to pump, by water or steam power, to a reservoir, stand-pipe, or directly into the distributing mains; those works owned by the public or by a private corporation, — in a word, the subject would include a record of the work of designing, constructing, operating, and maintaining every description of existing water-works systems.

To prepare a paper on a subject so important, to suggest the most feasible and practicable scheme for a system of records applicable to every water department in all its details, would be manifestly an undertaking of immense labor, and one involving a vast amount of time even by one competent to perform the task; moreover, the consideration of such a paper, assuming the work to have been done in such manner as to enable its author to present to you an exhaustive treatment of the matter, would be likely to profitably consume more time than you would probably have at your disposal at any one of our meetings. On this account it has seemed to me best to consider only the form and method of recording the daily work of such a system of water-supply as the majority of us

are daily associated with, leaving those larger, and, perhaps, more complex, for a future time and an abler advocate. I therefore take pleasure in approaching this subject by presenting for your consideration a short description of the form of records adopted by us at Newton as the result of about fourteen years' experience in water-works management. I do this, it is of course unnecessary for me to say, with no intention of claiming for it great superiority, or even especial merit, but simply with the feeling that in this manner the subject can best be introduced to you, and with the hope that as a result of the opportunity afforded you for comparing this system with your own, and by means of the discussion and criticism likely to follow, the entire matter of water-works records may receive the attention it deserves, and that we may be mutually benefited by giving to it at our future meetings more of the thought, study, and consideration to which its importance entitles it.

Before, however, touching upon our records, in order that you may as clearly as possible understand their application, it will be well for me, I think, to explain to you our situation at Newton, the character of our works and our form of government as it relates to the water department. As you are probably well aware, the city of Newton has a population of about twenty-three thousand people, distributed among ten different villages; it embraces in area 12,000 acres, and has 138 miles of streets. We obtain our principal water supply from an open gallery along the bank of the Charles river in the town of Needham, with a small auxiliary supply from driven wells on the Newton side of the river, near our pumping-station; the gallery is, speaking approximately, 1,600 feet long and 70 feet wide at the top, with sloping banks reducing the width to ten feet at the bottom; the water is conveyed from the gallery across the river through about 700 ft. of 24-in. pipe to a pump-well in the station, from which it is raised to our reservoir.

Our pumping plant consists of a 5,000,000-gallon compound duplex condensing-engine and a 1,000,000-gallon duplex high-pressure steam-pump, both of the Worthington make. Our reservoir is located on the easterly side of the city, about 3½ miles from the pumping-station; it has a capacity of 15,000,000 gallons, and its elevation affords an average pressure throughout the city of 60 pounds. We have about 87 miles of distributing mains, all of cast-iron, varying in diameter from 4 inches to 20 inches; on these mains are located 404 gates and 566 hydrants, and from them are supplied 4,000 service-pipes; on the service-pipes, for the measurement of water delivered, are placed 2,500 meters.

Conforming, I believe, to the universal custom in Massachusetts, the act of the Legislature authorizing the city to secure a water supply provided for the construction and management of the works under such rules and regulations, with certain limitations, as the city should see fit to adopt. The works were constructed by a commission wholly outside the city council, but upon their completion were turned over to the city, and managed for several years by a joint committee of the city government; for the last seven years, however, they have been in charge of a water board, which is composed of five members, three being selected from the citizens at large, and one each from the board of aldermen and the common council, the two branches of our government. The principal officers of the department, the registrar and superintendent, are appointed by the mayor, subject to confirmation by the board of aldermen, and hold office until death, resignation, or removal.

All the other employees of the department are appointed, and have their compensation established, by the water board. By an ordinance establishing the office of city engineer, he is *ex officio* the engineer of the board.

The action of the board is in a great measure controlled by the ordinance established by the city for the government of the department, but they have absolute control over all the department employees, except the appointment, removal, and establishment of compensation of the registrar, superintendent, and engineer. They have, consequently, authority, which they have exercised, to establish rules and regulations for the management of the works. Under these rules the registrar is the clerk and executive officer of the board, and to him daily all other officers of the department report, he being required to keep a careful and complete record of all the operations of the department, and to report thereon weekly to the water board.

In enumerating our system of records, we naturally begin with our source of supply. Although, as has been stated, we draw our water from a basin alongside the river, and although, as a matter of fact, we take very little water, if any, from the river, nevertheless, owing to a decision made in its wisdom by the Supreme Court of Massachusetts, we were obliged to pay to the mill-owners below us $25,000, for the privilege of taking from the river 1,500,000 gallons of water daily; it being therefore desirable to know approximately the quantity of water in the river, for the purpose of ascertaining how much damage would be caused the mill-owners if our authorized quantity should be exceeded, a daily record is made of the height of the water there. It is also desirable for us to know the height of the water in our filter basin, in order that we may know the supply we have in reserve. I have previously stated the dimensions of the basin, which has a capacity of between 5,000,000 and 6,000,000 gallons. Our pumping engineer, with very little trouble, attends to the reading of the river-gauge as well as that of the basin, and telephones the readings to the registrar's office, where they are recorded. A gauge, showing the height of the water in the reservoir, is taken twice a day, and also telephoned and recorded in a similar way. This latter, of course, gives us the quantity of water in reserve in the reservoir, and also shows, in connection with our pumping record, the daily consumption. An improvement on this system of reservoir-records is undoubtedly an automatic recording-gauge, such as has been the product of the genius of one of our fellow-members, and which not only keeps a continuous record of the elevation of the water in the reservoir, but automatically registers the elevation wherever required, regardless of its distance from the reservoir.

PUMPING-STATION RECORDS.

The importance of a complete record of work done at the pumping-station of a water department needs no emphasis at my hands to those of our Association, certainly, who are obliged to pump the water they use; only by such a record and a careful and constant study of it we can obtain the best results from our service.

The form adopted by us provides for a record of the time of start and finish of the run of the pumps; a record of the delivery of the pumps, including a reading of the counter, number of strokes, average per million gallons, length of strokes, and gallons pumped during run; a record of the water levels, including height of

pump-well, height of delivery, suction lift, static and dynamic head; a reading of the steam, vacuum, and water gauges; a record of the temperature of the atmosphere, engine-room, boiler-room, pump-well, feed-water, and air-pump delivery; a record of the water evaporated in the boilers; a record of the fuel used, keeping separately the quantity of coal used for raising steam and banking fires, for heating the building and for pumping; a record of the weight of ashes and clinkers remaining, and the duty record of the engine.

Under the rules of our board the pumping engineer telephones to the registrar at the close of each day's pumping the quantity of water pumped and the amount of coal used; he is also required to make weekly returns of a transcript of the record kept as hereinbefore described, which is recorded in the registrar's office.

DISTRIBUTION RECORD.

As I have before stated, our mains are all of cast-iron; they are made from specifications prepared by our engineer, with thicknesses computed by the Shedd formula, and are made with the Providence Bell. After they are cast they are inspected at the foundry, and a sworn statement of said inspection is forwarded to us, with the record of each individual pipe; on their receipt from the foundry they undergo a careful hammer inspection before acceptance; having successfully passed this inspection, they are placed in stock and charged to our stock clerk; it is his duty to know at all times how much pipe, as well as all other material, we may have on hand, and all pipe delivered by him is charged to the foreman taking it, who in turn reports the particular work in which it has been used, and to the expense of which it then becomes charged.

Applicants for extensions are required to file with the registrar a petition therefor setting forth that they own the premises for which the water is asked, and that they will take the water as soon as the main is laid, and conform to all the rules and regulations of the department; the superintendent then makes an estimate of the expense of the proposed extension, which is filed with the registrar, and upon which is based a guaranty that the petitioner is required to sign before further steps are taken in the matter; this guaranty provides for an assured income from the extension of 5 per cent. per annum of the cost of making it, exclusive of any receipts to the department from water sold to the city from hydrants, watering-troughs, etc., that may be placed upon the main in question. Before making the guaranty, there is deducted from the estimate the portion, if any, providing for the erection of hydrants, the city itself assuming this part of the expense.

The minimum time for which a guaranty is accepted is five years, and the requirement is often longer.

On an average there are always in force guaranties on 200 separate extensions of mains, and as these are made for varying terms, and begin and expire on all dates during the year, for properly keeping the accounts a book, provided with an index, and with the following headings, is necessary: Name of street; ward; date of laying main; length of term; amount of guaranty; and columns showing by years the amounts assessed, with the dates of payments.

Besides the guaranty, if the extension is requested for a street not accepted by the city, in other words, a private way, the petitioner is required to secure and

file with the registrar an agreement, signed by all owners abutting on the line of the proposed extension, that the city shall have the right to lay and maintain perpetually its pipe in said way. These papers being signed, they are laid, together with the petition, before the water board, and if the matter is favorably considered the extension is ordered laid. Extensions of pipe, as well as other out-of-door work generally, are made under the personal direction of the superintendent.

The board having acted favorably upon a petition, the superintendent is notified, and the order is placed on file, to be executed in its turn. The engineer is also notified, and establishes line and grade for the proposed extension. The work being undertaken, accurate record is kept, in the manner before outlined, of the stock of all description used therein, with an account of the labor performed; these returns are made to the registrar weekly, and from them the cost of the extensions are reported to the water board.

The engineer, besides giving line and grade, locates the pipes and makes a plan of the same for the registrar, on a scale of 600 feet to the inch. This plan also shows the position of all hydrants, gates, etc. Besides this plan, which is a general map of the city, the engineer provides sectional plans of the pipe-system, on a much larger scale, which are of especial value in looking up the location of service-pipes.

A description of the register used to record the details of extensions made is as follows: It is ruled in columns, providing for a note of date of laying of the main; the street and ward in which it is laid; the street connected with it; the size of connection main; cost of labor; cubic yards of rock excavation; the length in feet of size of pipe used; the cost of pipe; the number of pounds and cost of lead used; the number, kind, and cost of gates used; the number, kind, and cost of hydrants set; a description, weight, and cost of specials used; a description, with the amount of sundry expenses, including such as for teaming, blacksmithing, powder, and fuse, etc.; finally, a column showing the total cost of the extension, with another showing the estimated cost, for purposes of comparison.

As before stated, we have four thousand service-pipes in use. A petitioner for service-pipe is required to sign an application therefor, in which he agrees to pay such portion of the cost as we may assess upon him, and to take the water as soon as the pipe is laid. He is also required to deposit the estimated cost of that portion of the pipe upon his own premises, the city assuming the cost of the work in the street. The petitioner may elect the material for the pipe within his grounds, although the department strongly favors and recommends the use of lead.

The application being signed and the deposit given, an order is issued to the superintendent to put in the pipe, and notice is also sent to the engineer, who locates and plots the service, thereby incidentally furnishing a check upon the measurements returned by the foreman. As in the case of work on main pipe, a memorandum of stock used and labor performed is kept and returned to the registrar, by whom it is recorded in a service-register, arranged and ruled to take in the following-named data: Number of service; name of taker; street; ward; date laid; size of main tapped; size of service material; size and cost of corporation cock; cost of lead connection; distance from main to S.W. cock; S.W. cock to street line; street line to building; total length; cost per foot;

total cost of pipe; size and cost of S.W. cock; kind and cost of cover; cost of labor; cost of sundries; total cost to city; distance from street line to house; additional distance on premises; total length on premises; price per foot; cost of pipe to water-taker; charge for sŭndries; total cost of service to taker; date of adjustment of bill for service; and the date of turning on water.

Under a provision of our water ordinance the water board is required to attach meters to all services supplying other fixtures than faucets, also to fixtures supplying only faucets when more than three faucets are used; the board must also furnish meters to all water-takers desiring to use them, regardless of the fixtures supplied; the meters are furnished, maintained, and renewed at the expense of the city, except where they are injured through the negligence of a water-taker or by frost. The city charges a rental for their use, — the charge for the ordinary house-size meter being $2 per annum.

On receipt of meters from the manufacturer, they are carefully tested on $\frac{1}{4}''$ and $\frac{1}{32}''$ streams under a pressure of about 85 pounds; the results of these tests are entered in a "Record of Meter Tests," ruled to the following headings: Name of meter; pattern; size; number; length of test in minutes; size of orifice; number of feet run; weight of water in pounds; per cent. registered; and date of test. Upon being placed in service, a report is made and recorded as follows: Number of service; name of taker; number of meter; size; kind of fittings; cost of fittings; cost of setting; total cost.

OPERATION AND MAINTENANCE RECORDS.

The water having been conducted from the filter basin through the reservoir, distributing mains, and service-pipes, to the premises of the water-taker, upon application therefor and the adjustment of the bill for service, the pre-payment of that for water, and the setting of a meter, if one is required, an order is given for the turning on of the water to his house; such orders are upon written forms, and are returned duly indorsed by the person doing the work, with a statement of the fixtures in use. We are now ready to open an account with the water-taker, which we do in a book prepared especially for the purpose and known as our "Water Ledger;" he is there given the number assigned his service-pipe when laid. Our water ledgers are ruled for three accounts on a page, with a space for five years for each account. Over the headings are placed the service number; name of owner; name of tenant; street; ward; and description of premises. The headings are as follows: Charge for service-pipe; charge for building water; dates between which payment for water is made; number of faucets; cubic feet indicated by meter; gallons; rate per thousand gallons; amount due; date from which advance charge has been made; amount of advance charge; excess over advance; charge for sundries; abatement; amount paid; date of payment; amount and date of payment of meter rent; amount and date of payment of summons; date of turn off; date of turn on; date of sealing fixtures; date of payment of charges for turning off or on; sealing or unsealing; amount and date of payment of rebates. This form of ledger, which, it will be noticed, is applicable alike to metered and rated services, was devised to obviate the necessity of keeping separate ledgers for each class of water-takers; in it is provided appropriate and conveniently arranged space for

recording every description of charge, with its date of payment, that we are ever called upon to make against a water-taker. The accounts are arranged in these ledgers in the regular order of their service numbers; but they can be readily referred to when the number is unknown, by means of a card index, if the name of either the owner or tenant can be given.

The water bill for the fractional part of the year being paid, and the water turned on, no charge is necessitated against the taker until the end of the year, unless for some reason he has his water turned off, adds to his fixtures, or has his service or meter repaired.

Although the city owns and maintains all meters set since 1887, as has been previously stated, there were, when the ordinance providing for such arrangement went into effect, about one thousand meters which had been previously set by consumers and owned and maintained by them; to these the new arrangement does not apply.

No change in water fixtures can be made without the written permit of the board, and when application therefor is received, a record is made of the proposed change, and also of the report of the inspection of the premises which follows.

Repairs to services or meters may be the result of either a complaint from the taker of insufficient service or of a visit by the inspector to the premises

A regular inspection of fixtures is made once a year, and a record taken of the name of owner of premises, name of tenant, street, ward, number of families, number of persons, and the number and condition of fixtures.

Regular inspections of meters are made four times a year; other inspections of certain meters are made from time to time, when deemed necessary.

Our water year begins March 1, and all meter accounts are adjusted twice a year; a minimum charge of $10 is collected from each taker on March 1 and on September 1. If at that time any taker has used more than this amount will pay for, he is billed for the excess; this explanation is made for a proper understanding of our meter inspection book, which is ruled with the following headings: Service number; name of owner; name of tenant; kind of meter; number of meter; size of meter; reading March 1; reading in March, April, May, June, July, August; quantity of water in feet and gallons; value; reading in September, October, November, December, January, February; quantity of water in feet and gallons; amount.

Our city is divided into seven wards, and a separate book is provided for each ward, in order that the record of the inspections of either, when completed, may be immediately returned to the office, and the posting to the ledgers be thereby facilitated.

The inspection of fixtures and meters is made by our inspector, who also has charge of our meter department; by the rules of the board he is required to have charge of testing, setting, and repairing meters, and to keep a careful record of the dates and results of all tests made, and of the condition of meters removed for repairs, both before and after repairs are made, with the date of removal and resetting. He is also required to keep a careful record of the cost of setting, repairing, inspecting, and removing all meters from their date of setting, with the annual and aggregate expense of maintenance, computed both per meter and per one hundred thousand feet of water registered.

Mention has already been made of the form of books used in recording the results of testing the meters, and also that containing a record of their setting; that adopted to meet the remaining requirements of the rules of the board is provided with headings as follows: Service number; name of taker; street; ward; number of meter; size of meter; date of setting; cubic feet registered to date; water pressure in pounds; then columns for description and cost of repairs by years. Meters of different makes are recorded by themselves.

RECORD OF RECEIPTS AND EXPENDITURES.

Collections for our department are made by the city collector through bills issued by the registrar. The statement before made, that where over three faucets are used meters are set and consumers charged meter rates, must be amended by excepting certain supplies furnished the city. But the city is only excepted from the rule in the matter of charges for hydrants and street-sprinkling; for the former it pays us $20 for each hydrant set, and for the latter the regular rate for measured water, its bills therefor being based upon returns made to us by the contractors for sprinkling, of the number of loads they have distributed upon the streets. As the capacity of their carts is known, the quantity of water can be thus obtained with sufficient exactness, and the necessity is obviated of setting and maintaining upon the number of stand-pipes we have the large number of meters that would be required.

Based upon the February inspection of meters and fixtures that have previously been referred to, the annual water-bills are made out by the registrar and given to the collector on the first of March. For convenience in handling we use a different-colored bill for each class of charge; the bills are all of uniform size, with coupon to be detached by the collector upon payment. When the bills have been made out, a memorandum of them is made in a book ruled so as to provide for a record of service number, name of owner, street, ward, description of bill, amount of bill, abatement, and amount and date paid. This book is given to the collector, and its footing shows him the amount he is expected to collect. Abatements of the bills are made only on certificate from the registrar to the collector, and the amounts and reasons for making same are duly recorded and reported to the water board. After each day's collection the collector transmits to the registrar the coupons retained by him, which are entered by the registrar in a book known as the cash-book, from which they are posted to the ledger. Our cash-book is ruled to provide for the entry of service number; name of taker, with a separate column for every description of charge, for this purpose there being 21 columns provided; a column showing the total amount paid, with date of collection; bills for fractional supplies and for services and sundry charges are made out, recorded, collected, and payment posted in like manner.

The book-keeper of a private business has a distinct advantage over one in public service, inasmuch as he is but little liable to the annoyance of a change in the personnel of his employer; his superior either instructs him to prepare his books after a certain form, or authorizes him to open them after his own ideas; this being done, the employer, from his personal and financial interest in his business, naturally familiarizes himself with the system adopted, and thereafter to give satisfaction the employee has only to keep his books closely to date.

A public official, however, must go further than this. From the frequent changes that occur in the different boards and committees by whom his work is inspected, it is not only necessary for his books to be closely posted up, but also that they should be kept to show operations in minute detail and in a manner to be readily understood by any one, whether or not he possesses a knowledge of book-keeping.

This is especially true in the matter of the expenditures of a department. Not to speak disrespectfully of our superior officers, we all know that far too often the more important consideration of the manner of doing a piece of work is sacrificed to the consideration of its expense, and that, in general, the capacity of the public for criticism — never by any means small — finds full scope for action in attacking an administration through its expenditures, often when they have been made with the utmost conservatism.

The expenditure of the department at Newton to the sinking-fund for the payment, when due, of the water debt, and that for the payment of the interest on water bonds, is provided for by the city council upon recommendation of its finance committee; all other expenditures, with the exception of those for salaries, before referred to, are controlled by the water board. An appropriation is annually made by the city council for maintenance of the department; one for an account known as the service and meter account, and one for an account called the rebate account. To the first is charged all that portion of the expense of maintaining and operating the works which the city must assume; to the second all expense of new work, or of repairs to old work, which is chargeable to the water-taker; and to the third all expenditures made in refunding to water-takers any portion of the rates they may have paid us.

Expense incurred by extensions, and all new work not chargeable to the water-taker, is charged to an account known as the construction account, for which no annual appropriation is made, but for which money is provided by the city council from time to time as the need therefor occurs, upon the recommendation of the water board, by a further issue of water bonds.

Under the rules of the department no expenditure whatever can be incurred without authority from the board, who hold weekly meetings, at which requests for permission to make expenditures which meet their approval are duly granted.

The pay-rolls of the department are settled weekly, but all bills are paid once a month. The bills of the department, after receiving the approval of the board, are entered by the registrar in a book known as the "bill-book."

In this book the bills are first entered in detail, and then charged to an appropriate heading under an account called the expenditure account; to some division or divisions under this account the total of every bill must be charged, and there may be as many divisions, which are all numbered, as may be required. At the present time we use twenty-five divisions, a few of which, noted by way of illustrations, are as follows: (1) Stock; (2) labor; (3) registrar's salary; (4) superintendent's salary; (5) teaming; (6) travel; (7) small supplies; (8) inspection; (9) miscellaneous expenses. After being entered under the expenditure account, the amount of the bill is carried to one or more, as may be, of the four remaining divisions of the page provided respectively for the maintenance, service and meter, construction, and rebate accounts. Each of these accounts may be

subdivided, like the expenditure account, as much as needed; some of the divisions used by us are, for the maintenance account, (101) water board; (102) registrar's office; (103) superintendent's office; (104) reservoir; (105) mains. For the service and meter account, (201) new service; (202) maintenance of service; (203) maintenance of meters. For the construction account, (301) new mains; (302) new hydrants; (303) new services. For the rebate account, (401) water rebate; (402) meter rebates.

As before stated, the full amount of every bill must appear in the expenditure column, and must also appear as a whole in either of the other four columns, or be divided among them as may be proper. For example: a certain pay-roll amounting to $432.59, as kept by us, would be charged under the expenditure account to (2) labor, $421.05; and (10) pumping-station salaries, $11.54,—which two charges would make the total of the roll; it would then be charged under the maintenance account to (111) standpipe, $3.50; (114) pumping-station, $11.54; (118) water troughs, $3.55; under the service and meter account it would be charged to (201) new services, $14.95; (203) maintenance service, $3.64; (204) maintenance meters, $8.00. Under the construction accounts it would appear thus: (301) new mains, $324.80; (303) new services, $47.23; (314) new meters, $15.38.

For another example let us take that of a bill for hydrants amounting to $100; after being copied in detail it will appear under the expenditure account, charged to (1) stock, $100; and again, under the construction account, charged to (302) new hydrants, $100.

It will be observed that the footing of the expenditure account must agree with the total of the bills entered, with which also must correspond the aggregate footings of the maintenance, service and meter, construction. and rebate accounts.

The especial advantage of this form of bill-book lies in the fact that it shows at a glance not only the amount of all expenditures, but the purpose for which they have been made, and the particular part of the work to which they have been charged.

Besides the bill-book are kept separate books for all the accounts above mentioned, appropriately ruled for their various sub-accounts, into which are posted monthly from the bill-book the required entries; there are also kept, besides these books, a journal and ledger, which, being of ordinary form, need no especial mention.

And now, gentlemen, having given you some idea of water-works records as kept by us, and thanking you for the patient attention you have given me, I resign the subject into your hands. If anything I have said shall prove of benefit to you, as your friendly criticisms will surely be to me, I shall feel amply repaid for the time spent on the matter. But I hope, nevertheless, that the subject will not be allowed to rest here. I do not think the importance of properly keeping the record of daily work in a profession like ours can possibly be overestimated. Particularly is it of importance to those of us having charge of a public system. If it is essential — and we all know that it is — for every private business of whatever nature, or however small, to be intelligently systematized, and to have its daily operations carefully recorded, of how much greater moment is it for us who labor for the public, and who are constantly under the supervision of the people's eye,

always critical, often unfairly so, — of how much greater moment is it for us, I repeat, to endeavor not only to accomplish all we undertake, be it work in-doors or out-of-doors, above ground or deep down in the earth, in the best possible manner, but also to so record our doings, that why a thing was done, how it was done, when it was done, and the expense of its doing, may at any time be ascertained, and readily ascertained, by any one having the right, who desires to know. We should not forget that though the works we build and manage may endure for all time, that we ourselves are here but for a moment; therefore, let us each so care for his charge as to make it possible for those who follow us to say, "He was a good public servant," realizing that by our records alone shall we be remembered.

THE ANALYSIS OF WATER, — CHEMICAL, MICROSCOPICAL, AND BACTERIOLOGICAL.[1]

BY

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It would surprise most persons, I think, if they should look closely at a sample of pond or river water in a clean, white glass vessel. Water which we ordinarily think clear and colorless is then often seen to contain a good many floating particles, some pollen-like in appearance, others looking like shreds or fibres, organic *débris* of various kinds, and it may be, too, little white jumping water-fleas. After the water has stood quietly for several hours, some of these particles will sink to the bottom of the vessel and form a sediment.

Under the microscope many of the small particles which appear to the naked eye as mere points, or fine lines, are seen to be living vegetable and animal organisms, the variety of which is often very great and the number enormous.

Natural waters also contain much that cannot be seen with the naked eye or with the microscope, — that is to say, substances in solution, including organic matter, mineral matter, and gases, which can only be recognized by chemical means. Then there are the minute organisms known as bacteria, too small to be recognized except under the very highest power of the microscope, for the investigation of which a special method of bacterial culture is employed.

We shall be aided in the study of the complex composition of natural waters if we first consider how this infinite variety of forms and substances get into the waters. If we go back to the source of all waters — the rain — we find that, distilled water though it is, it is far from pure. It contains in solution the oxygen, nitrogen, and the carbonic acid of the air, and any other gases that may be present, as the sulphurous vapors from the smoke of cities, and also the dust and dirt which may be floating in the air.

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[1] A lecture delivered before the Lowell Institute, Boston, Dec. 5, 1889.

As soon as this water touches the ground it starts at once for the sea. Let us imagine that it first falls on steep mountain slopes, far from the dust and smoke of cities, where the rocky bed and the rapid descent afford but little opportunity for the water to take up any foreign matters. These rapid mountain streams are justly associated in our minds with the idea of high purity. When the stream reaches more nearly level ground its progress is slower, and there is time for the water to dissolve from the ground any soluble matters which may be present. If the water flows through marshy lands it will acquire a yellowish-brown tint from vegetable coloring matters. All soils, too, give up to water in soluble form more or less mineral matter, particularly those of a calcareous nature. If the stream is sufficiently large and rapid, some of the earthy matters of its banks and bed may be carried along in suspension, — matters which settle to the bottom when the water is at rest. Thus in still bodies of water, which occur in the course of a stream, — the lakes and ponds, — we find the water generally free from suspended earthy matters; but it is in these bodies of still water that we find the greatest number of living organisms suspended, — the microscopic animal and vegetable forms.

This stream, with its ponds and lakes, which we have pictured, is, thus far, *normal*, a term which I would apply to natural surface-waters which have received nothing in any way connected with the life of man. Normal waters differ widely among themselves, according to the regions through which they flow. Some of them are but little removed from complete purity; some of them are far removed from it; but they are free from the waste products of human life and industry. The distinction is a useful one. All normal waters are not necessarily good waters to drink, but they can never cause those specific troubles which have their origin in the wastes of human life.

Following still further the onward-flowing stream, we find it coming within the sphere of man's activity, as, for instance, where it flows through land devoted to tillage and pasture, where the organic matter in the soil is largely of animal origin, from the fertilizers used and from the excreta of cattle. In farming regions the proportion of refuse from cattle is greater, as well as more widely disseminated, than that from man. When the stream passes through cities it receives the abundant and varied waste of human life, included under the name "sewage;" and it may be that the much-abused stream may be still made to bear the waste of factories which pour their often foul-looking and ill-smelling refuse into it. The water which left the sea pure and empty-handed, returns to it laden with the spoils of the land, the waste of the rocks and the soil, and the waste of life.

The elementary conceptions with regard to a water analysis are: —

1st. That we may have substances in water both dissolved in it and floating or suspended in it.

2d. That we may have animal, vegetable, and mineral substances in water, and all of them may be in solution, or all of them may be simply in mechanical suspension.

3d. That this animal and vegetable matter may be living and thriving in water, or it may be dead; and, further, that the non-living matter may be permanent, that is, with little or no tendency to decay, or it may be readily putrescible.

We can put the subject in another way; namely, we want to learn from an analysis not only what is in the water, but what is going on. Mineral matter, whether suspended as clay or dissolved as salt, suffers no change on standing, but animal and vegetable substances are susceptible both of growth and decay. From a sanitary stand-point it makes a great deal of difference, as we shall see, whether a water containing organic matter is permanent or undergoing change.

Before discussing the composition of water from a strictly sanitary stand-point I wish to call your attention to the mineral ingredients of natural waters which determine its value for many domestic uses. The most common mineral substance found in water is lime, any considerable amount of which makes the water hard; that is, it curdles soap, and no lather can be made with the water until all of the lime present has first combined with soap, making a curdy precipitate. The other mineral bases commonly found in waters are the alkalies, potash, and soda, and magnesia, also alumina, and oxide of iron. In combination with these bases are silica, sulphuric acid, carbonic acid, and chlorine.

The classification of waters, on the basis of mineral matter, may be made, first, as regards the amount of the mineral contents, and second, as regards their character. Thus, we distinguish between mineral waters and drinking waters, though it is not easy to say just at what point water ceases to be a potable water and becomes a mineral water. The popular distinction is as good as any; namely, that the mineral waters have enough mineral matter in them to give a taste to the water, and potable waters do not. The taste of a water is, however, a matter on which there is wide difference of opinion. When it is said that a water is good-tasting, some would mean, simply, that it was not ill-tasting, while others would mean that the taste was distinctly agreeable. Decided preferences for the water of a particular well or spring, as having an especially good taste, or as being especially refreshing, are very common. This is often merely a matter of temperature of the water, and not of taste. Taste is communicated to waters by the soluble salts and soluble gases. Distilled water is said to be flat and insipid, because it has lost its gases; more likely, because it has lost its salts. Pure carbonated water — that is, distilled water containing an excess of carbonic acid in solution — is sharp and pungent, but has none of the savor due to mineral matters. All the artificial carbonated table waters have a little salt or alkaline carbonates added to take off the flatness that pure carbonated waters have. It is not uncommon on shipboard, where distilled water is used for drinking, to add a small amount of alkaline salts to make the water more palatable.

To return from this digression, we distinguish, as I have said, mineral waters from drinking waters by the amount of salts in solution. But another distinction, and a very important one, entirely independent of the amount of salts present, is between saline waters and alkaline waters. The former, the saline waters, are in general like sea-water, though, of course, much more dilute. The mineral matter is mainly chloride of sodium — common salt — with variable proportions of lime and magnesia. The latter, the alkaline, contain mainly carbonate of soda, with variable proportions of carbonate of lime and magnesia, and generally much carbonic acid. The first class are represented by the bitter saline of St Catherine's, Ontario, and the second class by the alkaline waters of Vichy and Carlsbad. Between these extreme types there are intermediate degrees, and we have natural mineral waters, like those of Saratoga, which are both saline and alkaline.

Surface waters — streams and lakes — contain, as a rule, much less mineral matter than ground waters, simply because they have less opportunity to dissolve them. Many surface waters in this vicinity contain only about 1 to 5 parts per 100,000 of mineral matter, or 0.5 to 3 grains per gallon. In limestone regions the surface waters are higher in mineral matter by reason of the ready solubility of lime in water containing carbonic acid. Saline lakes, like the Great Salt Lake and the Dead Sea, are abnormal, the accumulation of saline matter in them being due to the fact that they have no outlet, and that the evaporation from the surface is equal to or exceeds the water flowing into the lake.

A ground water contains mineral matter in character and amount dependent on the kind of rocks with which it has associated. The decay of the rocks, by the infiltration of atmospheric water, is a slow process, but one always in progress. By this means alkalies, lime, and magnesia are dissolved as carbonates together with silica, leaving a residue of insoluble clay. Waters which drain regions of crystalline rocks contain in solution carbonates of potash and soda, and relatively much silica. Such waters, filtering through soil, are deprived of their silica and potash, which enrich the soil, and lime and magnesia go into solution as bicarbonates.

When carbonated waters act at great depths, under high pressure and at a high temperature, as, for instance, in the Yellowstone region, the decomposing effect on the rocks is very much enhanced, and springs of high mineral contents result, often containing much silica in solution.

An analysis made to determine whether a water is wholesome or not is made in a different way, and from a different point of view, from an analysis made to determine the character of its mineral contents. In both cases the analysis reveals to some degree the history of the water, — where it has been, and in what company; but the sanitary analysis concerns itself mainly in knowing what is the present condition and past history of the water as regards animal and vegetable life. To say that a sanitary analysis is one which is chiefly concerned in the *life history* of a water expresses well its object and scope.

A prevalent notion regarding the methods employed to determine whether or not a water is good to drink is that a chemist makes his tests for the unwholesome substances, just as he would make a test for arsenic or lead in the water. It may, perhaps, be a statement that will surprise many of my hearers when I say that, apart from vegetable or mineral poisons accidentally present in water, a chemist has never yet found any substance in water which he could say with certainty was of itself the cause of disease.

A thorough sanitary analysis of water is three-sided, —

First. The solid matter in the water is separated by filtration, transferred to the slide of a microscope, and examined. This tells what animal and vegetable forms are present. By taking measured amounts of water and counting these forms a quantitative determination of them may be made.

Second. A very small amount of water is tested, by a method to be presently described, to determine the number of bacteria present.

Third. The chemical analysis is concerned in discovering the amount and kind of mineral and organic matter in the water. If organic matter is present, its character and condition must be investigated to see whether it is capable of decomposition, and whether it is in the process of decomposition. If no organic

matter is present, then the mineral matter must be examined to see if any of it had its origin in organic matter. From the data thus collected — the microscopic life, the bacteria, the amount and condition of the organic matter — we draw our conclusions as to the sanitary quality of the water.

It is a common notion that a drop of water seen under the microscope will reveal such a frightful collection of animal life that one will have a well-grounded distrust of water ever afterwards. Many of us can recall with what fascination and horror we first saw the fearful-looking monsters projected on a screen from a magic-lantern. But if the microscopist should go about his work in this way, looking at single drops of water, it might be very long before he would be rewarded by the sight of anything at all. The method he uses is to filter a considerable quantity of water through cloth, or, better, fine sand. This intercepts the organisms, which can then be transferred to a slide and examined.

A good ground water, free from organic matter, should contain no life of any kind. It may contain plant food; but green plants cannot grow in absence of light, and fungus growths, which do not require light, need organic matter. If we find life (vegetable or animal) in well-water it is because the conditions of growth are present, and this is abnormal and suspicious.

In surface waters the conditions are different. Ponds often swarm with life, and the water is not necessarily the worse for it. The vegetable forms commonly met with in water comprise the algæ, among which we distinguish the green, the blue-green, and the brown-green, or the diatoms, which live, like other green plants, on mineral food, and the fungi, which have no chlorophyl, and cannot live entirely on inorganic matter.

The green algæ, common forms of which are Spirogyra, Volvox, Draparnaldia; and the diatoms, among which may be mentioned Asterionella, Melosira, Synedra, Pinnularia, — live abundantly in waters of good ponds and rivers. They may be sometimes themselves the cause of unpleasant tastes and odors, but their presence does not indicate anything objectionable in the water in which they live. The blue-green algæ, which also live in good waters, — at least in waters which are entirely free from human wastes of any kind, — attain, at times, an enormous development in ponds and reservoirs, and become a nuisance by reason of the rapid decay of a jelly-like substance which they secrete. Cœlosphærium, Anabæna, Clathrocystis, Oscillaria, and Nostocs are varieties of these blue-green algæ.

The most frequent animal forms may be grouped under the Rhizopods, the Infusoria, the Worms, and the Entomostraca (or water-fleas). A good surface water may contain any or all of these animalcules in small numbers, and their presence in such waters may actually contribute to its excellence, provided they be few. The presence of large numbers, however, justifies suspicion, since it indicates decomposable organic matter present in the form of food, and may also lead to bad tastes and odors as the outcome of their vital activity. Some infusoria, such as Euglena, and some worms, such as Anguillula, and certain rotifera, seem to indicate considerable contamination, since they seldom occur except in polluted waters, where, it is to be inferred, they find appropriate food, *i.e.*, abundant and possibly solid and easily decomposed organic matter.

The fungi are to be interpreted very differently from the animal forms which, in their lack of chlorophyl, they resemble. Like the animals, they are dependent

upon foods more highly organized than merely mineral matters; but, unlike the animals, they do not absolutely require what is commonly known as "organic" matter. They are able to live upon the least decomposable kinds of organic matter, upon which no animals could survive. Hence their presence is not necessarily suspicious.

Some of the fungi absolutely require certain mineral matters, and it seems not to matter so much with them as to the rest of their food. The fungus, Ceggiatoa, called also the "sewage fungus," is known to thrive in sewage-polluted waters, and hence its presence in a water has been thought to indicate the presence of decomposing animal matters. But the substance that the Ceggiatoa absolutely needs for its life is sulphur, and that seems to be the reason why it grows so luxuriantly in sewage waters, which always contain more or less sulphuretted hydrogen. It is said that this fungus grows equally well in natural sulphuretted waters, provided there is some kind of organic matter present.

There is another interesting fungus, found both in surface and ground waters, called Crenothrix. For its growth iron is necessary. A very remarkable case of rapid development of this fungus occurred in the Berlin water supply a few years ago. Water drawn from wells on the borders of Tegel lake, perfectly clear and colorless as it came from the ground, became, on exposure to the air, turbid, and deposited a rusty-brown sediment consisting of this Crenothrix and oxide of iron. The iron was in the water in the form of protoxide, in very small amount; but there could not be any oxidation in the ground, and consequently no growth of the Crenothrix, because of the absence of oxygen. On the exposure to the air, however, all the conditions were present for its rapid growth. No means could be thought of to stop the trouble, and the supply from this source had, therefore, to be abandoned. The same trouble exists at times, during warm weather, at the Wayland water works in this State, where water is drawn from filters on the bank of a reservoir.

The total number of organisms in any sample of surface water is often very large — 25,000 to a tumblerful is not an unusual number for Cochituate. In the Newton water there are no organisms as it comes from the ground, but on exposure to the air the growth of diatoms is often so enormous that 1,000,000 to a tumbler would not be an exaggeration.

The bacteria belong to the lowest form of life; a simple cell, with wall and contents, capable of self-nourishment and reproduction. Until within a few years their presence was unknown and unsuspected, so minute are they, and yet their importance in the economy of nature is such that higher life would come to an end if their activities were to cease. It is unfortunate that these ever-present, humble, useful organisms should be associated in our minds mainly with evil purpose and effect. True, there are malignant bacteria, to which we cannot assign any beneficent rôle in nature; but so there are poisonous fruits.

The bacteria, or germs, as they are also called, have many shapes: the ball or egg-like forms include the genera micrococcus and streptococcus; the rod-like forms, the genus bacillus; and spiral forms, the genus spirillum. A special form of bacteria we have all become familiar with in name, — the cholera germ, called by Koch the comma bacillus.

The function of the green plants is to make organic material out of the inorganic. Trees, grass, and vegetables live entirely on the carbonic acid of the air

and the water and mineral matters in the soil. Animals cannot do this, but require either vegetable or animal food. In utilizing this food the animals do not reconvert it all into mineral matter again. The nitrogen in the proteid, or albuminoid matter which they consume, is not excreted in the oxidized form of nitrates, but as urea, a compound related to ammonia. Then the bacteria step in, find food for their support in the waste which has no more value for animal life, and complete its conversion into mineral matter that it may again serve as food for plants.

This is only one aspect of bacterial life, but it is the one most closely related to the subject we have in hand. Bacteria are also capable of beginning with the albuminoid matter and carrying it through all the changes which result in its complete oxidation. It matters not to them whether their food is, say, the albumen itself, or what man discards after having used the albumen for his food; the bacteria will accomplish the same end in both cases, namely, the complete mineralization of the organic matter. These busy, active bodies have this function: to take organic matter or organic waste, break it up, rearrange its atoms, and deliver back to the earth again the mineral matter which the plants have taken from it.

This sounds almost like a tale from wonderland, and yet these changes are very familiar to us all. We call them by various names, — oxidation, decomposition, decay, putrefaction. It was formerly thought to be purely a chemical process. By exclusion of the air, as in the various processes of preserving foods by canning, decay could be averted; but in the presence of air the processes of oxidation were supposed to be necessary and inevitable. To-day we know that there will be no change in organic matter, even in air, if these micro-organisms are excluded or rendered inactive.

Just a word with reference to the method used to determine the number of the bacteria in water. It is based on the principle that by stimulating their growth, and making them increase enormously within a small space, in which they cannot move, the aggregations of the newly developed bacteria will be so large that they can be seen by the naked eye. This ingenious suggestion was carried out by the famous bacteriologist, Koch, in this way: A small quantity, usually one cubic centimeter, of the water (that is, about one-fifth of a teaspoonful) is mixed thoroughly with, say, ten times its amount of a sterilized solution of gelatine, which contains extract of beef, peptone, etc., to make it highly nutrient, and the mixture is poured, while warm, upon a glass plate, so that it forms a thin layer when solidified. This is set aside for a few days in a warm room under a cover and protected from the germs in the air. If bacteria are present in the water they will grow with great rapidity under these conditions, each bacterium forming a colony, as it is termed, of thousands or millions of bacteria. Then we can see and count them. It is assumed that each colony arose from a single bacterium in the water; hence by counting the number of colonies on a plate we arrive at a determination of the number of bacteria in the cubic centimeter of water used.

The numbers of bacteria, as determined in this way in natural waters, vary greatly. A water taken directly from the ground, at a depth of six feet or more, should contain none. In good pond waters may be found anywhere from a few score to a few hundred. In polluted streams they may run up well into the

thousands or hundred thousands, and in sewage they can be sometimes counted in the millions.

The most obvious inference to be drawn from the presence of living bacteria in water is the same as that drawn from the presence of any kind of life; namely, that there is food for them there, and the greater the number of them the more abundant the food. This is the simplest expression of their silent testimony to the quality of the water. At the present moment we cannot stop to speak of the many conditions which may modify this testimony. Let it suffice for our present purpose that bacteria in water mean decay of organic matter, and that their number bears some relation to the amount and rate of decay going on. At a subsequent time we shall return to them and study their diverse activities somewhat more closely.

Organic matter is composed of carbon, hydrogen, oxygen, and nitrogen; at least, for our purpose it will suffice if we so consider it. It is only the nitrogenous organic matters which undergo those kinds of changes which we include under putrefaction, and which we regard of importance from a sanitary stand-point. Familiar examples are milk and meat, which when exposed to the air become offensive, but starch and sugar (which contain no nitrogen) do not.

A typical nitrogenous substance we have in albumen, which is a product of both animal and vegetable life. It contains about sixteen per cent. of nitrogen. Animal tissues and fluids are largely composed of albuminous or proteid substances, as they are called; vegetables contain them only in small amount. Muscle, which forms a large part of the higher animals, contains about fourteen per cent. of nitrogen. The cereals contain about two per cent.

The nitrogen, which we find on analysis from undecomposed animal and vegetable matter, say fresh albumen, we call "organic nitrogen," by which we mean that the nitrogen is still in its original organic combination before change or decay has set in.

The first stage of decay is the oxidation of the carbon, either from the oxygen of the substance itself or oxygen from without, and this leaves the nitrogen and hydrogen, which unite to form ammonia. The determination of carbonic acid, as an evidence of beginning decomposition in water, is of but little value, since carbonic acid is present in the atmosphere, and may come from many sources; but the determination of the ammonia thus formed is of the greatest significance. Leaving out of consideration that present in rain-water, we may say that ammonia in water is distinctly characteristic of the first stage of the decomposition of organic matter.

As decomposition progresses the ammonia itself is oxidized, — both of its elements, — the hydrogen to water, and the nitrogen first to nitrous acid, and lastly to nitric acid. The acids thus formed combine with some of the bases present, let us say potash, and we have neutral compounds formed which remain in solution in the water. The potash compound of nitric acid is common nitre or saltpetre. This process of nitrification which goes on in water on a very small scale is the same by which saltpetre is made on the large scale in nitre beds, where rapidly decomposing animal matters are mixed with bases, such as lime or potash, and exposed freely to the air.

The principal object of a sanitary chemical analysis of water is to determine the amount of nitrogen present in these four forms: organic nitrogen, ammonia,

nitrous acid, and nitric acid. The significance of these determinations is this: organic nitrogen represents the possibilities of putrefaction still remaining in the water, ammonia represents decay begun, nitrous acid (or the nitrites) represents decay still further advanced, and nitric acid (or the nitrates) represents the completion of those oxidizing processes which, taken together, we call decomposition or decay.

The nitrates are purely mineral substances, all traces of the organic origin of their nitrogen being lost, and they have no more significance in water analysis, *as such*, than if we had taken a pinch of nitre and added it to the water. I say as such, for you read in some books on sanitary matters of the "deadly nitrates" in water, when the fact is that the nitre in natural waters is in no wise different from the nitre we eat on corned beef. But the significance of the nitrates is this, they tell of a past history of a water which may be far from praiseworthy. High nitrates in water means that there was once much organic nitrogen and much decay going on in that water, and possibly some taint may hang around it still.

The organic nitrogen, representing organic matter which has not begun to decay, has generally been thought particularly objectionable in water because it carried with it the possibility of further decay with all its attendant dangers. But this view ignores the fact of the great dissimilarity of organic substances in this respect. Animal matters, as we all know, are, as a rule, much more readily putrescible than vegetable matters, and the products of their putrefaction are usually more offensive. Much of the vegetable matter, particularly that which gives a brown color to the water, is, in reality, very stable, and to class the organic nitrogen in a substance of this character with that contained in a substance like albumen in blood is a manifest absurdity.

To have but the one idea of nitrogenous organic matter in water, namely, that it is inherently capable of decomposition, and to make no distinction as to the likelihood of its decay, is so obviously an inadequate view of the subject, that no importance can be attached to opinions based merely on the presence of organic nitrogen.

It is a well-known fact that sea-captains going on long voyages have taken with them by preference dark, swampy waters, because they keep particularly well. These waters show on analysis high organic nitrogen, and would on most English standards be condemned as "polluted."

I have thus far used the term "organic nitrogen" as expressing precisely the idea which I wish to convey, but on the tables of analyses[1] before you, you will not find this expression, but in place of it another, which I have not hitherto mentioned, namely, "albuminoid ammonia." It is an unfortunate fact that our methods of determining organic nitrogen have been, until recently, very tedious and difficult, and not always reliable, so that chemists have resorted to another process, which gives only a part of the organic nitrogen in the form of ammonia. That is called albuminoid ammonia, because albumen, when subjected to this process, gives up its nitrogen as ammonia.

The process in question, invented by Wanklyn, Chapman, and Smith many years ago, is so easily and quickly performed, and gives results of such great

[1] The tables are not reproduced in this publication.

comparative value, that it has come into almost universal use, so that in the very large majority of water analyses made at the present day albuminoid ammonia takes the place of organic nitrogen. From a long series of experiments I have made, I think it safe to say that the albuminoid ammonia, as determined in most of the surface waters of this State, is about one-half of the total organic nitrogen in the water.

Beside the determination of the organic matter in the water, the determination of the amount of chlorine has the greatest significance, from the fact that the waste of human life in its various forms contains a large amount of salt — chloride of sodium. The finding in a water, therefore, of a large amount of salt, or what is the same thing, of chlorine, is strong evidence of the presence of drainage or sewage in the water. That this evidence should have any value, it is obvious that the amount of chlorine in the water in its natural condition must be known. No natural waters are without some chlorine, but the amount varies very widely. Streams and wells in the regions of salt deposits may contain a very large amount, and waters near the sea are also apt to be high in chlorine. To form any opinion of the character and history of a water from its chlorine contents, without knowing the *normal chlorine* of the water of the region, is clearly impossible.

The systematic examination of the waters of Massachusetts instituted by the State Board of Health has enabled us to establish the normal chlorine for all parts of the State. To do this it is necessary to know by actual inspection that a water, say a brook with a limited drainage area, receives no house drainage whatever. Repeated determinations of chlorine in the water extending over a year or more, in dry and wet seasons, will give an average of normal chlorine contents for this drainage area. This has been done for the whole State, with the practical and eminently useful result that we are able to tell with high probability when any stream is contaminated with drainage, and to just what extent. In general it has been found that for the surface waters of this State the amount of chlorine decreases as we go westward from the sea.

The instances in which this minute knowledge of the normal chlorine of the State has proved of value in detecting pollution in surface waters have been very numerous. I will mention one instance. In the samples regularly received from the water supply of a town in the western part of the State, the chlorine was found to be slightly, yet persistently, above the normal of the region, and, together with this, the ammonia was repeatedly higher in amount than was consistent with our notions of a good pond water. Inquiries as to the possibility of contamination elicited only the statement that the pond received no drainage of any kind, and that the drainage area was almost free from population. It looked very much as if the value of the normal chlorine determination was to be seriously impaired by reason of this unfortunate exception. But a visit to the locality revealed the fact that the pond supplying the water was a reservoir formed by damming a very small brook, a mere thread of a stream, and that in a field through which this brook ran, but a few rods before it widened out to form the reservoir, cows were grazing, and some were standing in the brook itself. So small was the size of the reservoir that the water which left this field in the morning might be supplied to the consumer before night. A sample of water from the same brook was then taken about half a mile or more above this field,

on land free from all pollution, and to our satisfaction it was found to have only the amount of chlorine which the region called for.

These normal chlorine determinations apply primarily to the surface waters of the State. The ground waters follow, in general, the same rule of increasing chlorine from west to east; but inasmuch as many of the rocks contain some chlorides, which can be leached out by the waters in long contact with them, the regularity of the increase cannot be so confidently relied upon, nor can we be so sure that the normal chlorine determined in one ground water will apply for any large radius around it.

Let me give an instance of the application of this idea of local normal chlorine to the detection of pollution of a well by drainage. A householder in a suburb of Boston having had several cases of sickness in his house, had the water of his well examined. It was found free from organic matter, but with very high mineral contents, including high chlorine and nitrates. Contamination of the water of the well by the drainage of the house was said to be impossible, such were the relative positions of well and cesspool. The evidences of local contamination. furnished by the chemical determination, were strong enough to make one doubt the testimony thought to be based on positive knowledge. The simplest way to decide the matter was to find, if possible, what was the normal chlorine in the ground water of this region. Fortunately there was another well in the same body of gravel on which the house was built at a slightly greater elevation; the water of this well was examined and found to contain only about one-tenth as much chlorine as the water of the suspected well. Digging revealed the fact that the house-drain to the cesspool passed near the well, and that this portion leaked, so that the ground around the well was thoroughly soaked with decomposing matter.

In the description of the general nature of the chemical analysis of water which I have just given I have had mainly in mind the analysis of surface waters containing life, animal or vegetable, with their possibilities of decay. The ground waters are very different in character. A good ground water, from spring or well, should be both colorless and clear, with no trace of turbidity and no trace of life. Of organic nitrogen, of ammonia, and of nitrites there should be none; but nitrates are generally present. As we shall see in a subsequent lecture, the most favorable conditions for the oxidation of organic matters are those which exist in porous soil, so that water containing nitrogen in any form becomes, when slowly percolating through soil, entirely purified; that is to say, the nitrogen is all converted into the mineral form of nitrates. When the water which we draw from the ground has never known other forms of nitrogen than that derived from the ammonia of the air, or the vegetable matter on the surface, then we find the nitrates very low; they may even be entirely absent; but when as surface water it has been contaminated with animal refuse, then we find the nitrates high. These two substances together in water — the nitrates, and the chlorine when above the normal — give evidence which is absolutely conclusive that the water in some part of its course has been in bad company. If we can be sure that the last traces of organic matter are destroyed, with all the intermediate products of decomposition, and that all the bacteria with which this organic matter was originally swarming are dead, then the presence of the chlorine and nitrates need not worry us. But can we ever be quite sure of this?

When the source of pollution is near, we may have a water free from organic matter to-day and full of it to-morrow, — a possibility which is more remote in proportion as the source of pollution is farther removed. There can be no rule given to cover all cases of this kind; each one must be the subject of special investigation as to source, nature, or distance of the organic matter. But one principle it is well always to bear in mind, it has been well expressed by Dr. Kedzie, of the Michigan State Board of Health: "In a drinking-water, what we demand is innocence, not repentance."

In the tables before you with the heading Sanitary Analysis you will notice many other determinations than the four forms of nitrogen and the chlorine to which I have referred. They are color, odor, turbidity, and sediment of the water, the total solids, loss on ignition, change on ignition, and the hardness. To this list I might have added others, as the oxygen dissolved, the oxygen required to oxidize the organic matter, and many others in ordinary use, which give valuable information as to the origin and condition of the water. A full description and discussion of these chemical determinations are clearly out of the question in the time we have to devote to the subject, and I have thought it more profitable to confine our attention mainly to this one side of the chemical study in water, namely, the detection of harmful pollution by means of the changes in nitrogenous matter. This, taken in connection with the evidence offered by the chlorine, will, if correctly interpreted, generally lead us in the right direction.

It will be of assistance in recognizing in an analysis the evidence of pollution of a water, if we take a nearer view of the character and composition of the typical polluting material, namely, sewage.

Sewage is the water supply of a city as it passes out. It is a very variable substance. It differs in composition in different cities, and in the same city it differs in character at different seasons of the year, and even at different times of the day. The greater the amount of water used *per capita* in a city, the more dilute the sewage will be; the sewage of a manufacturing city is of a different character from that of an exclusively residential city. Sewage flowing at night will naturally have less solid matters in it than that flowing by day; and if the rain-water, also, has access to the sewers, the sewage of wet weather is very much thinner than in dry weather.

But certain things characterize all sewage, and distinguish it from the water supply; namely, an increase of mineral matters, including salt, and an increase of nitrogenous matter, in the first stage of decomposition, that is to say, with high ammonia.

Sewage is not attractive in appearance, and our associations with it are far from pleasant, and yet the amount of decomposing matter in it is really very small. Suppose it contains one hundred parts of solid matter per one hundred thousand, a rather large amount, this means only one-tenth of one per cent., or fifty-eight grains to the gallon, a considerable part of which is mineral matter. Another way to put it is, that sewage is over ninety-nine per cent. water.

The condition of the nitrogen is significant and characteristic. It is mainly in the form of free ammonia, the albuminoid ammonia (or organic nitrogen) being always very much less. There is none of the nitrogen oxidized, and the sewage contains no free dissolved oxygen. All the oxygen that was originally in the water has been consumed in the oxidation of the carbon of the organic matter,

and it has not sufficed to oxidize any of the nitrogen. The organic part of sewage may thus be said to consist of nitrogenous matter in the act of decay, and that this decay has been temporarily arrested by the failure of the supply of oxygen. As soon as it gets more oxygen, by exposure to the air, or by flowing into water which is abundantly aerated, decomposition is resumed, for the bacteria of decomposition are all ready to begin operations again as soon as the necessary oxygen is available.

If now we look for evidence of sewage pollution of a water in its contents of nitrogen, we shall find it in the free ammonia, if the pollution is recent and near by; but if the pollution was more or less remote, and there has been opportunity for oxidation of the nitrogen, then we may expect the presence of nitrites and nitrates. The chlorine, and the mineral contents in general, will not change in character or amount, but the relative amounts may be much reduced by dilution.

From analyses of water, such as I have described, what have we learned? First, by means of the microscope, the kind of life existing in the water, from which we draw conclusions as to the kind and quality of the food which supports this life. Second, by means of the gelatine plate cultures, the number of the bacteria in the water, from which we draw conclusions as to the amount and kind of decay going on. Third, the chemical examination reveals to us directly the amount of organic matter and the conditions in which it exists. These widely different methods are merely different points of view. It is one and the same thing throughout which engages our attention; namely, the life processes which are going on in the water, for decay is but the manifestation of another form of life.

If it is asked why our study is centred here, the answer is simply, that experience has taught us that it is the organic matter which is the cause or accompaniment of disease; it is in the decomposition of this organic matter, somewhere in the changes that it undergoes in the process of decay, that danger lurks. This is the chemical expression of the causation of disease. The biological expression takes another form; namely, that the bacteria which cause changes in the organic matter, cause also disease. The two expressions do not contradict each other, but go hand in hand. The specific action of the bacteria will be more fully discussed in the next hour, — let the chemical idea suffice for this, namely, that *the state of change is the state of danger.*

NEW ENGLAND WATER WORKS ASSOCIATION.

ORGANIZED 1882.

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This Association, as a Body, is not responsible for statements or opinions of any of its members.

JANUARY MEETING.

YOUNG'S HOTEL, BOSTON, Jan. 8, 1890.

President Brackett occupied the chair at the January meeting, which was held at Young's Hotel, Boston, January 8. The following-named gentlemen were in attendance: —

Solon M. Allis, Superintendent, Malden, Mass.
R. W. Bagnall, Superintendent, Plymouth, Mass.
Dexter Brackett, Superintendent, Boston, Mass.
Geo. F. Chace, Superintendent, Taunton, Mass.
R. C. P. Coggeshall, Superintendent, New Bedford, Mass.
F. H. Crandall, Superintendent, Burlington, Vt.
Lucas Cushing, Assistant Superintendent, Boston, Mass.
Edwin Darling, Superintendent, Pawtucket, R.I.
Nathaniel Dennett, Superintendent, Somerville, Mass.
F. F. Forbes, Superintendent, Brookline, Mass.
Frank L. Fuller, Civil Engineer, Boston, Mass.
John A. Gould, Jr., Assistant City Engineer, Boston, Mass.
E. H. Gowing, Civil Engineer, Reading, Mass.
J. C. Haskell, Superintendent, Lynn, Mass.
L. E. Hawes, Civil Engineer, Boston, Mass.
Wm. M. Hawes, Commissioner, Fall River, Mass.
Geo. A. Kimball, Civil Engineer, Boston, Mass.
W. F. Learned, Assistant City Engineer, Boston, Mass.
Hiram Nevons, Superintendent, Cambridge, Mass.
Geo. J. Ries, Superintendent, East Weymouth, Mass.
W. H. Richards, Superintendent, New London, Conn.
A. H. Salisbury, Superintendent, Lawrence, Mass.
Geo. A. Stacy, Superintendent, Marlboro', Mass.
L. A. Taylor, Civil Engineer, Boston, Mass.
D. N. Tower, Superintendent, Cohasset, Mass.
C. K. Walker, Superintendent, Manchester, N.H.

F. W. Wilder, Treasurer, Woodstock, Vt.
Geo. E. Winslow, Superintendent, Waltham, Mass.
E. T. Wiswall, Commissioner, Newton, Mass.
M. F. Wright, Superintendent, Lowell, Mass.
E. R. Jones, Boston, Mass.
Prof. T. M. Drown, Massachusetts Institute Technology.
D. J. White, Clerk Common Council, Pawtucket, R.I.
Z. R. Forbes, Assistant Superintendent, Brookline, Mass.
J. G. Dennett, Pumping Engineer, Salem, Mass.
Edward Sweeney, Commissioner, Marlboro', Mass.
Chas. W. Holyoke, Commissioner, Marlboro', Mass.
Wm. G. Goldthwait, Commissioner, Marblehead.
A. P. Barrett, Water Registrar, Woburn, Mass.
P. F. Crilly, Superintendent, Woburn, Mass.
A. W. Worthley, American Frost Meter Company, Boston, Mass.
J. M. Betton, Henry R. Worthington, Boston, Mass.
B. F. Brodrick, Chadwick Lead Works, Boston, Mass.
A. W. Deane, Deane Steam Pump Company, Holyoke, Mass.
H. A. Gorham, Gilchrist & Gorham, Boston, Mass.
Albert S. Glover and H. D. Minton, Hersey Meter Co., South Boston.
H. F. Jenks, Fall River, Mass.
C. H. Baldwin, National Meter Company, New York.
F. P. Stevens, Peet Valve Company, Boston, Mass.
C. E. Roberts, Hartford Steam Boiler Inspection and Insurance Co., Boston.
J. P. K. Otis, Union Meter Company, Worcester.
B. F. Polsey, Walworth Manufacturing Company, Boston.
E. L. Abbott, Water Waste Prevention Company, New York.
J. P. Blossom, Whittier Machine Company, Boston.
Charles H. Eglee, Contracter, Flushing, N.Y.

After dinner had been served the meeting was called to order by the President, and the Secretary presented the following names of candidates for election to membership: —

RESIDENT ACTIVE MEMBERSHIP.

Lewis M. Bancroft, Chairman Water Commission, Reading, Mass.
Walter Hale, Civil Engineer, Westfield, Conn.
Arthur F. Salmon, Member Water Board, Lowell, Mass.
F. P. Webster, Superintendent Water Works, Lake Village, N.H.
Philip J. Doherty, Member Water Board, Boston, Mass.
Charles E. Drake, Civil Engineer, New Bedford, Mass.
Z. R. Forbes, Assistant Superintendent Water Works, Brookline, Mass.

ASSOCIATE MEMBERSHIP.

Wilmer Reed, Agent McNeal Pipe and Iron Co., Burlington, N.J.

On motion of Mr. Hawes, the Secretary was authorized to cast the ballot of the Association for the applicants, which he did, and the President declared them elected members.

The following papers were read and discussed by the Association : —

" Notes on Laying a 20-inch Main," W. H. Richards, New London.
" Water Supply at the Boston Fire of Nov. 28, 1889," Dexter Brackett.
" Stealing Water," G. A. Kimball.
" Laying of a 10-inch Pipe in Leicester, Mass.," F. L. Fuller.
" Effect of Water-hammer in Cement Pipes," G. L. Winslow.

The papers were discussed by Messrs. Jones, Hawes, Fuller, Darling, Tidd, Gowing, Stacy, Walker, Barrett, Nevons, Allis, Crilly, and Haskell, after which the Association adjourned, to meet on February 12.

NOTE. — The above papers and discussion will be printed in a future number of the Journal.

SOME NEW EXPERIMENTS AND PRACTICAL TABLES RELATING TO FIRE STREAMS.

BY

JOHN R. FREEMAN, Hydraulic Engineer.

Presented at the meeting of the New England Water Works Association, Boston, December 11, 1889.

A little more than two months ago I presented to the American Society of Civil Engineers an account of an extended series of experiments upon Fire Streams. Your President and Secretary have requested me to present this matter to your attention at this time by reason of the peculiar interest which recent events give to the subject of fire protection, and from a belief that to you, as the gentlemen who supply the water which the fireman uses, the practical tables accompanying the original paper would have value. I would refer any of you who may happen to desire full and complete knowledge of the means by which these tables were derived, to the "Transactions of the American Society of Civil Engineers" for November, 1889, as that memoir, and not this address, is intended to be the scientific record.

Within the past fifteen days the value of ten million dollars has gone up in smoke within ten miles of the spot where we meet to-day. As an eye-witness to these fires I have seen abundant proof of the importance of the scientific study of water supply in its relation to fire protection.

In the ordinary average year the destruction by fire in the United States alone is upward of one hundred million dollars; and in the United States alone it is estimated that twenty-five million dollars are spent in maintaining fire departments.

It is the furnishing of water for fire purposes which measures the capacity of your pumps and pipes and gives them their severest test.

Thus there need be no apology for the subject to which attention is directed at this, our first dinner of the winter, and I trust you may not find the flow of water in hose a dry subject.

In this large gathering I see so many new faces that I am tempted to follow the advice of the eloquent Motley, who said that when an unknown author presents his views upon an important theme he should begin by stating who he is.

Some of you, gentlemen, have had occasion to know me as one who vigorously holds that water-meters on a pipe supplying automatic sprinklers are a device of the devil; others among you recognize in me a man who sometimes suddenly opens a dozen hydrant streams at some mill-yard, just to see what your water works are good for, or to demonstrate to a mill manager that his boast of their excellence is a delusion and a snare, and so stirs things up that that end of the town gets muddy water for a few days.

Still others of you know me as an engineer who tries to combat the false doctrine held in some "back towns," that forty pounds is a "fire pressure," or the more prevalent error that a six-inch pipe a mile long will supply half a dozen good fire streams, or may have heard me advocate the doctrine that the man who lays a long four-inch pipe for a hydrant main ought to be banished from the land of combustible architecture.

To the others among you I beg to say that by education and profession and love for the work, I am a hydraulic engineer, and at present hold the position of engineer to an association of insurance companies.

In one small corner of the broad field of hydraulics I have tried to rear a modest structure resting on a secure foundation and fairly well finished throughout, and in building this structure I have earnestly tried to avoid using second-hand lumber.

I had for some time previously regularly used in my practice the tables of Geo. A. Ellis, a member of this society, and was also familiar with the published results of the experiments of another engineer, well known to you, Mr. E. B. Weston, of Providence.

One should speak well of the old bridge that has oft served his convenience, and the thanks of the craft are still due Mr. Ellis for the eminently practical and convenient form to which he reduced his results.[1]

When it was attempted to apply the Ellis Fire Stream tables to exact and accurate work there was trouble, for the discharge by these tables differed from plunger displacement more than could be attributed to "loss of action" in the pump.

And as to loss of pressure by friction in rubber hose, these tables gave but one value for the loss in a given length under a given discharge through common $2\frac{1}{2}$-inch fire hose, thus implying that the conducting power of all kinds was practically alike. Yet, from examining different samples, it was evident that the differences in smoothness of waterway and differences in actual diameter must make the friction loss very different in different kinds of hose, and the exact kind which happened to be experimented on by Ellis was not known.

Turning to Weston's experiments, his results, except for the 1-inch smooth nozzle, were left in a form somewhat unhandy for ordinary use, being stated

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[1] Departing for a moment from this strict line of our subject, it may be said that I consider the shape in which Mr. Ellis presented his little table for the flow of water in pipes in his book on Fire Streams (p. 38) is by far the most convenient form that has appeared, although in some cases I might, perhaps, prefer to slightly change the figures.

only in algebraic formulæ, and although his estimates of the quantity discharged from nozzles appeared reasonable and are since proved to have been accurate, yet his experiments on friction loss in hose took no cognizance of these differences in diameter or character of surface, and were rendered just a little uncertain from having been all made with hose coupled with the old-style coupling, whose bore was $\frac{1}{4}$ inch smaller than that of the hose. Mr. Weston would no doubt gladly have left the matter in more complete form had occasion permitted, and the conscientious care and general accuracy of his experiments remain unquestioned.

For unlined linen hose, of which thousands of feet are sold yearly to be used in certain dry indoor places, for which, if honestly made, it is the best kind of all, there were no experiments on record anywhere.

I was therefore earnest and anxious for more light on this subject, and on my presenting the matter to the association of underwriters known as the Associated Factory Mutual Insurance Companies of New England, they provided the funds to meet the very considerable expense required for apparatus and assistant observers.

The subjects investigated were: —

First. Gallons per minute discharged under various pressures by nozzles of about 40 different shapes and sizes.

Second. Loss of pressure by friction in fire-hose of various degrees of smoothness and under various different velocities of flow.

Third. Effect of curves and crooks in the line of fire-hose upon loss of pressure.

Fourth. Effect of reduction of area of waterway at couplings upon loss of pressure in hose.

Fifth. Height and distance reached by jets of water under various pressures and from nozzles of various size.

Sixth. Difference between height or distance of extreme drops as measured at a firemen's muster and the height as a good practical fire stream.

Seventh. Comparative efficiency of ring nozzle *vs.* smooth nozzle, and of other kinds.

Eighth. Distribution of velocity in jets, or comparative swiftness of current at various points in the cross-section of jet as it issues from nozzles.

Finally. Practical tables were computed covering the range of sizes commonly used.

The experiments were made at the Washington Mills, Lawrence, and through the kind influence of your member, Mr. Hunt Salisbury, the city generously coöperated in permitting the free use of the excellent public water supply.

A full technical description of the details of the experiments is given in the Transactions of the American Society of Civil Engineers for November, 1889, which paper most of you would find very dry and tedious reading. You, gentlemen, are of an eminently practical turn, and will, I think, be interested chiefly in the practical results; but that you may have confidence in these results, I must give a brief description of the means taken to insure accuracy.

The experiments were made about a year and a quarter ago. The field-work occupied about two months, and the computation and reduction of the notes into practical form occupied most of my evenings from August to May.

Pressure Gauges.

In measuring pressures, for most practical purposes the ordinary Bourdon gauge is a very convenient, satisfactory instrument; but if one wishes to measure pressures and do very accurate scientific work in which it shall be absolutely certain that the gauge error is not one or two pounds to the hundred, then the ordinary forms of Bourdon gauge and even the expensive "test-gauges" are somewhat uncertain.

They are subject to unaccountable little variations, coming no doubt from the liability of the curved tubular spring to "take a set," and from the way an exceedingly minute change of form is exaggerated and multiplied by their levers and gears.

I therefore designed two light and portable open mercury columns, each about twenty feet tall and registering up to about 120 lbs. pressure, and used these in all the more important determinations. On these a difference of one-hundredth of a pound was distinguishable, and a tenth of a pound was indicated with positive certainty.

Measuring-Tanks.

To measure the number of gallons of water flowing per minute I had a square or rather oblong tank holding 1,450 gallons constructed of plank, timbered it heavily enough so it could not spring perceptibly, and then lined this with sheet-zinc, with the joints all soldered perfectly tight. I had means of measuring the depth in this tank to about the one-hundredth part of an inch. We measured the time of filling the tank by a stop-watch read to tenths of a second (though probably not really sure of this time much closer than a quarter of a second), and taking all things into account it appeared impossible for any measurement of the gallons per minute flowing to be more than a half of one per cent. in error.

Piezometers.

The next point was to attach the pressure-gauge to the hose or to the base of the play-pipe or nozzle so as to measure the exact pressure with accuracy.

This might appear the simplest thing in the world; and so it is, if one goes to work the right way. If one is working for accuracy, great care must be given to the proper arrangement of this "piezometer," as it is commonly called by engineers, and which means simply the pressure-gauge orifice in the wall of the pipe or hose.

If it were attempted to connect the gauge (as I have seen done) to a piece of ⅛-inch pipe tapped into the side of the main pipe and projecting a little into the pipe, the current flowing past this projecting end would, if the current were swift as that in a fire-hose, cause such a sucking effect as to make the gauge read one or two pounds too low.

For accurate results our piezometric hole must have its edges exactly flush with the inside surface of the conduit or pipe, and without the slightest projecting roughness or burr; it must be drilled exactly square to the axis of the pipe, and the direction of the current must be parallel to the wall in which this piezometric hole is drilled.

So simple does this whole matter seem, that many of you will be surprised to learn that some of the most eminent hydraulic engineers have seriously ques-

tioned whether it were really possible to measure the pressure with great accuracy through a hole thus drilled in the side of a pipe, and will be surprised, perhaps, to learn that one of the most skilful hydraulicians of the time, Mr. Hiram F. Mills, of Lawrence, spent several months' time and quite a good many hundred dollars in investigating and settling this very point, and determining just what conditions were necessary to insure accuracy. I was an assistant to Mr. Mills at the time these experiments were made, some fifteen years ago, and by reason of the knowledge there gained gave much care to my piezometers, and for these experiments designed some of the form shown below.

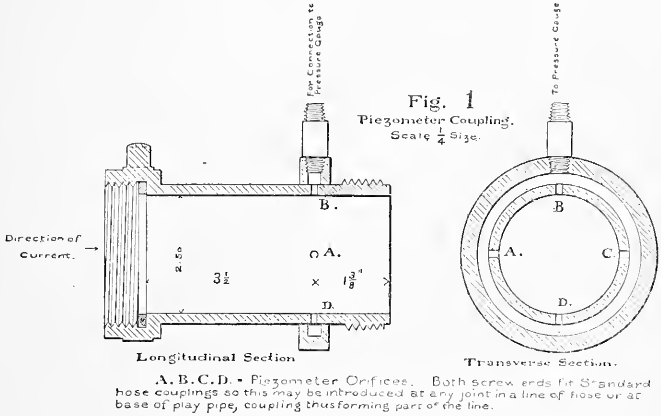

FIG. 1.

You will notice that there are four holes in the side of the pipe, all communicating with the hollow ring surrounding its outside. The object of so many of these was to obtain the true average pressure, if, as is sometimes the case with a swift velocity and a pipe not absolutely straight, the current happened to set a little harder against one side than the other.

The next step in the road toward accuracy is to be absolutely sure that the rubber tube or pipe, if more than a few inches long, leading from the piezometer to the gauge is filled with water and is absolutely free from air or bubbles, as these lighten the water column and make the gauge read too high. Therefore the connecting-tube should all the way run on a slope up toward the gauge; and a cock must be provided close to the gauge, which, being opened before the experiment, will allow the water pressure to drive out the air.

I have mentioned these items with some fulness, since I am addressing a body of men who often like to do a little hydraulic experimenting on their own account, and because we have whole rafts of experiments floating down the records of hydraulics which are next to worthless as data, because such precautions have not been observed.

The Source of the Water Supply.

In addition to the city pressure, which at this point is about 75 lbs. and very free from fluctuation, we had the mill fire-pumps at command, and could thus raise the pressure to 130 lbs. As the air-chamber on these pumps did not insure quite so steady a pressure as was desired, I extemporized a gigantic air-chamber by drawing off the water from the fire-pipes throughout the mill, which is a very large one (about fourteen acres of floor), and after these were filled with air connected them with the pump-pipe; and we had no trouble from small pipes at this mill yard, for I had planned them myself some years before, and the yard main was 16 inches in diameter.

Quantity Discharged by Nozzles.

So much for some of the means and appliances, now for the experiments.

The first which may claim our attention are those to determine the gallons per minute discharged by a nozzle of a given size under various pressures.

The general arrangement of the apparatus is shown in Figs. 3, 4, 5, and 6, on opposite page.

The piezometer (Fig. 1), which I have already described, was screwed between the base of a play-pipe and the end of the hose, and the water pressure at that point thus measured by means of the mercury gauge. The jet pointed upward as in practice, and after the stream had got into a condition of steady, regular flow the jet was caught by a hood and let fall into the measuring-tank. One observer read the pressure-gauge each half-minute; another worked the stop-watch, and measured the depth in the tank; and another manipulated the nozzle and regulated the pressure.

We experimented in all upon nearly forty different nozzles, — smooth nozzles, ring nozzles, plain nozzles, fancy nozzles, and of size varying from a $\frac{3}{4}$-inch up to a Siamese nozzle of $2\frac{1}{8}$ inches in diameter. The experiments, besides yielding a rule or formula by which the delivery of almost any nozzle of a given diameter can be accurately computed, and by the aid of which the discharges in the tables presented at the end of this article are computed, also yielded the following interesting points: —

The first point of interest was that it was proved in such a manner as to leave no room for doubt that the *Ellis tables are seriously in error* in their estimate of discharge, and that the actual discharge of any ordinary smooth nozzle is about $18\frac{3}{4}$ per cent. greater than stated in the Ellis tables. For ring nozzles the Ellis tables were also found to be seriously in error; the true discharge being about $15\frac{5}{8}$ per cent. greater than given by Ellis. It may be stated also that Mr. Weston's experiments on nozzles give results agreeing well with those obtained by me, and also disproving those of Ellis, and that records of certain results by earlier experimenters also are at variance with the Ellis tables. This unaccountable error in Ellis' work is greatly to be regretted, since, owing to their convenient form, his results have been copied and reproduced into numerous trade catalogues and hand-books.

The second point of interest was that *a ring nozzle of ordinary form* with shoulders $\frac{1}{16}$ to $\frac{1}{8}$-inch deep *discharges only about three-fourths as much water* as a smooth nozzle of the same size. Any one may illustrate this readily in a rough way to his own satisfaction by calipering the stream from a ring nozzle close to

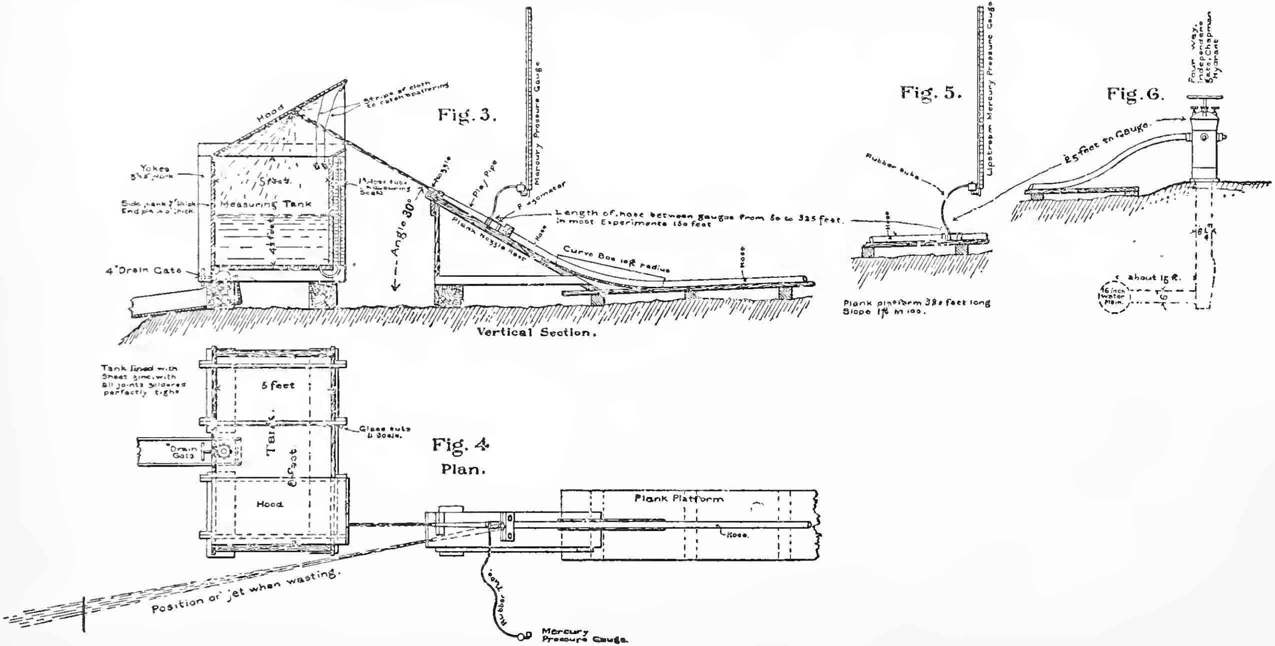
Fig. 3.
Hood
Strips of cloth to catch spattering
Yokes
Measuring Tank
5 feet
4½ feet
4" Drain Gate
Angle 30°
Nozzle
Mercury Pressure Gauge
Length of hose between gauges from 50 to 325 feet.
in most Experiments 150 feet
Curve Box 10 ft radius
Hose
Vertical Section.
Fig. 4
Plan.
Tank lined with Sheet zinc, with all joints soldered perfectly tight
5 feet
Tank
Drain Gate
Hood
Plank Platform
Hose.
Position of jet when wasting.
Rubber Tube.
Mercury Pressure Gauge.
Fig. 5.
Rubber tube
Upstream Mercury Pressure Gauge
Plank platform 38 feet long
Fig. 6.
Four way, Independence Gate, Chapman Hydrant
25 feet to Gauge.
about 15 ft.
16 inch Water Main.

Figs. 3, 4, 5, 6.

the outlet. The jet from 1⅛-inch ring will be found only about one inch in diameter, or of approximately ¾ of its area.

Third. The general hydraulic law that *the discharge of a nozzle is in proportion to the square of the pressure* was found to apply with great exactness. In other words, the coefficient of discharge was found constant for the different pressures within the range of experiments.

Fourth. For measuring water under high pressures *the nozzle furnishes a means of measurement fully as accurate, and even more accurate, than the weir*, providing the pressure is measured close to base of play-pipe by an accurate gauge attached to a suitable piezometer like that shown in Fig. 1.

This was proved by the general agreement in the relation of the theoretical discharge to the actual discharge (or coefficient of discharge, as we call it in hydraulics), in experiments upon fifteen or twenty different smooth nozzles.

It was also proved by experimenting with six different 1⅛-inch smooth nozzles in which the diameter of the orifice was practically identical, but which nozzles were of different forms of convergence and of different shapes on the inside, and which, moreover, having been made in different shops and by different workmen, had their waterways polished out with somewhat different degrees of skill and smoothness. If any of you have a special interest in this matter, you will find the experiments recorded in detail in the paper as published in the Transactions of the American Society of Civil Engineers, Nov., 1889.

For these different nozzles it was found that under a pressure of 30 lbs., and again with a pressure of 40 lbs., at base of play-pipe, the difference from the least to the greatest, in their rates or coefficients of discharge, was less than three-fourths of one per cent.

In other words, it was, I think, proved beyond question that having by good experiments determined that the coefficient of discharge for a smooth nozzle of an ordinary good form like that which I have here, and which is shown in Fig. 21, is, say, 0.977, we can rely with certainty on the fact that for any other smooth nozzle of exactly this same size of outlet and of somewhere near the same shape, the discharge for any given pressure will be the same within a half of one per cent.

Now, a half of one per cent. is exceedingly close work in a hydraulic measurement, and it is to be understood that this degree of accuracy is to be warranted only when the pressure measurement, the arrangement of piezometer, and the calipering of the diameter of the nozzle are all done with the greatest care.

Some books on hydraulics recommend the use of a sharp square-edged orifice as a means of gauging the flow of water. The edges of such an orifice are never absolutely square and sharp, and if diameters happen to be not more than one or two inches, the slight rounding of this corner makes the measurement of the effective diameter uncertain to a degree which may easily introduce errors of one per cent. in the computed discharge. In this regard the nozzle is practically far superior to this in accuracy, since, if well made, its diameter can readily be calipered with certainty to the thousandth of an inch.

The Nozzle as a Water Meter.

For general purposes of measuring great volumes the weir must ever remain the standard method, but for measurements of smaller volumes under high pressure, the nozzle as a gauging instrument has, I believe, a high value.

To avoid possible misapprehension I would distinctly say that the tables at the end of this paper are not designed for this *extremely accurate* gauging, but are arranged rather for the quick and handy use of the water-works superintendent or of the insurance inspector, and would say, that for this extremely accurate work the pressure must always be measured close to the nozzle.

A committee of the American Society of Mechanical Engineers has under consideration the question of a standard method for pumping-engine tests. The difficulty and expense of providing a weir at many places where direct pumping is done has led one prominent member of this committee to advocate the occasional use of the pump itself as a water meter, making corrections for clearance and slip, and length of stroke.

To me it seems this is liable to be too uncertain in an important test, and I would therefore suggest the nozzle.

I am at present making preparations for some tests on certain small pumping-engines, and have under construction a new pattern of Siamese nozzle which, although intended to be as good as the best for throwing a $1\frac{3}{4}$ to a $2\frac{1}{2}$ inch fire stream, is also especially adapted for use in measuring water. I had hoped to have this here to exhibit to you to-day, but from Fig. 2 you will see how handy is its application.

I would remark, however, that this sketch was made before the apparatus itself was built, and that the apparatus is less unwieldy than the sketch (Fig. 2) might imply. The barrel is of $3\frac{3}{4}$ inches internal diameter.

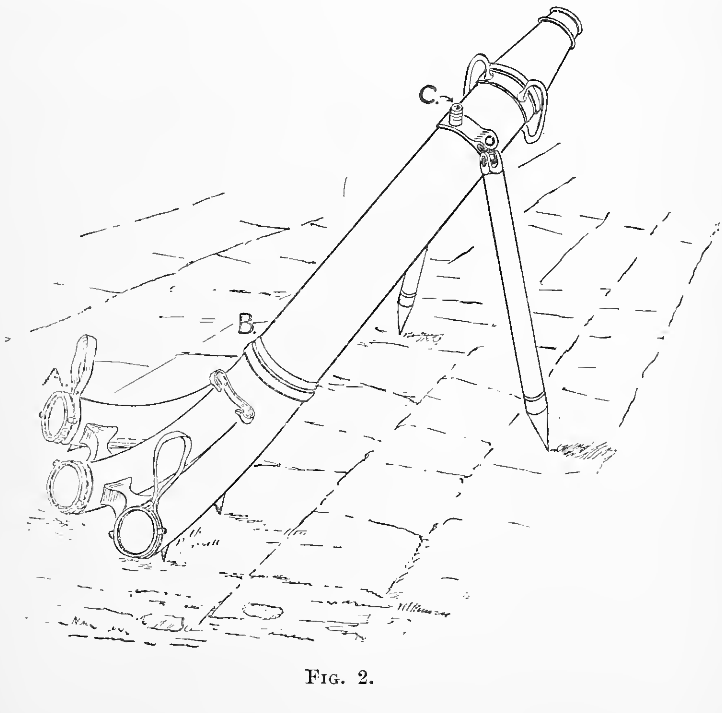

FIG. 2.

The peculiarity of this Siamese nozzle lies in the great care taken to so shape the waterways where the three streams unite and bend upward, that no whirls or eddies shall be produced in the current of water.

First. The bends upward are circular arcs carefully made tangent to the axis of the play-pipe, —and made plane curves, avoiding even the slightest warping or corkscrew-like twist, lest the water current be thereby set rotating.

Second. The cylindrical cross-section of the waterway of each of the three branches was carefully merged into V-shaped section where the branches united near B, thus preserving a thin partition of metal between each, so the currents do not unite until the straight single pipe is reached at B.

Third. The area of each waterway was carefully and gradually reduced as the branches came together going toward B, so that the water moves about 15 per cent. faster at B than at A. This gradual convergence tends to prevent eddies in the water at the concave side of the bend.

Fourth. Hollow cross-connections between the three branches at A were formed in the casting, so that in case one line of hose happened to be delivering more water than the others, the currents would, under the influence of the diminished area at B, tend to equalize, and thus give a more uniformly distributed current in pipe approaching the nozzle.

Fifth. To further reduce the liability to twisting of the currents, a thin 3-way "rifle blade," so called, extends from B for 16 in. toward C, this being set so that the blades halve the current from each of the three branches. At C is a hollow ring covering four orifices, and thus forming a piezometer on the same principle as that shown in Fig. 1. The ends at A are each fitted with an ordinary hose-coupling. Claws on the bottom of Siamese prevent its kicking back, and two light movable props, which can instantly be folded up out of the way and held in the spring-hooks alongside the barrel, serve to conveniently support it at any convenient angle, as shown.

This, all complete, will not weigh more than 75 pounds, and except for the pattern-work, which absorbed a good deal of time, by reason of the care taken in trying to give the curves and junction an almost mathematical exactness of form, would probably cost less than $100, exclusive of the pressure-gauge. One man can carry it easily from place to place, can set it up all ready for use in ten minutes, and yet it will, I think, prove equal to the gauging of a flow of 1,400 gallons per minute, or at the rate of 2,000,000 gallons per 24 hours, with an accuracy and certainty not excelled by the best-arranged weir.

All the setting-up required is to connect three lines[1] of good, new rubber-lined hose into it, and all the change or fittings required about the pump would be simply to attach some hose-valves to its force main. A table or a diagram of discharges for each pound of pressure can be prepared easily, so nothing will be necessary but to read the gauge and refer to the table for the gallons per minute.

A larger apparatus on the same plan could of course be made to take more lines of hose and measure the capacity of a larger pump, or a number of the smaller ones could be used.

I shall test this, and will let you know how practical use proves it. I have already done some experimenting with a less perfect apparatus, or I might not be so sanguine about this new one. It strikes me there are some other purposes about water works for which this simple, accurate, and portable water meter of great capacity would be useful, such as testing a pipe line for obstruction, or for measuring the volume that the distribution system could supply at a given point in the city without reducing the pressure below a given point. Moreover, a contrivance of this size, or larger, would be handy for the engineman to have at hand to test his pump with from time to time to see if the "slip" were becoming too large.

[1] I expect that it will also serve to take care of the water from four lines of hose, by connecting a common 2-way Siamese into the middle branch.

For a "duty trial" where large interests are at stake a mercury pressure-gauge would be most exact and satisfactory. Still, the Bourdon gauge will measure the water-pressure here as well as it will the steam-pressure, and will even do it better, or, in fact, about twice as well, for 2 per cent. error in the nozzle-pressure will cause only about 1 per cent. error in the discharge.

A good Bourdon duplex spring gauge, if compared and rated before and after the test by the beautifully simple and accurate (if properly used) gauge-tester made by the Crosby Gage & Valve Co. will answer almost every practical purpose.

The Venturi meter of Herschel will doubtless prove a very valuable instrument for the same class of work, of measuring large volumes under pressure, or for a permanent apparatus; but for temporary use in cases where the escape of the water is allowable the nozzle will, I think, unquestionably prove the cheaper and simpler, and give a little more precision of measurement.

As I said above, this very handy apparatus, while capable of serving for the most accurate kind of a meter, is also adapted for use as a piece of heavy artillery by the fire department; and the care taken in shaping its waterway, where the three streams merge into one, gives a freedom from eddies and twists and cross-currents in the nozzle which will, I trust, make it shoot a considerably more clean and solid jet than that ordinarily obtained from a Siamese nozzle.

Loss of Pressure by Friction in Fire-Hose.

This is the next point of interest connected with the experiments. This friction loss was determined for fourteen different kinds of 2½-inch hose. These were intended to represent all the typical kinds of hose in ordinary use, but no attempt was made to experiment upon all the different makes, sizes, and brands in the market, — these being so very numerous. The tests embraced leather hose, solid rubber hose, unlined linen hose, and rubber-lined hose of various kinds. Not only was 2½-inch hose tested, but some experiments were made with hose of 2 inches and 2¼ inches in diameter. A surprising difference was found in the conducting power of the different kinds of hose.

The hydrant-pressures in the different experiments varied from 15 to 125 pounds per square inch, and the delivery of the hose from about 50 to 325 gallons per minute. We thus had velocities of flow ranging all the way from 3 to 21 feet per second.

The details of the experiments are fully described in the Transactions of the American Society of Civil Engineers, to which I have already referred, and extended tables are there given showing the gauge reading, the lengths, the delivery, and the friction loss for 124 different experiments. It is hardly worth while to go into details here, but I will try to give, briefly as may be, the general results of the experiments.

General Arrangement of the Apparatus.

The effort was made useless in all respects to reproduce practical conditions as nearly as possible. The hose was connected to a Chapman hydrant at its upstream end, and nozzles of first one size and then another, varying all the way from three-quarters of an inch up to one and three-quarters inches in diameter, were attached to the down-stream end. The hose rested upon a uniformly sloping

plank platform about 350 feet in length, and the length of hose at one time under experiment varied anywhere from 50 to 325 feet. Although 325 feet was the greatest length used in any case, the results of the experiments are entirely applicable to any length however great, even up to half a mile, as the friction loss determined for 100 feet would be substantially the same for any other 100 feet of the same hose under the same conditions. It may be stated that experiments made first with a line of hose 300 feet long, then 150 feet, then 100 feet, and then 50 feet of the same hose, showed that the loss was, as might be supposed, strictly proportional to the length of the hose; in other words, with any given number of gallons per minute flowing, the loss of pressure in a line of hose 300 feet long was found to be almost exactly three times as much as the loss of pressure in a piece 100 feet long.

The pressures within the hose at various points were measured by means of mercury gauges and the piezometers already mentioned; the piezometers being coupled into the line between two sections of the hose at any desired point. Although the pressure directly at the hydrant was noted in many of the experiments, yet the up-stream piezometer and pressure-gauge from which friction loss was computed were generally located 25 feet down-stream from the hydrant, in order to get the pressure at a point far enough away from the hydrant to be certain that the current had got into a regular condition of steady flow. The measurement of the number of gallons of water discharged per minute was for those pressures, as well as for those on nozzles, made in the tank already described.

Care was taken to support the rubber tubing which connected the piezometer with the pressure-gauge so it should be on an even slope upward toward the gauge, in order that air-bubbles might not lodge and affect the results. Moreover, just before and after each set of experiments a waste-cock connected directly to the gauge was opened for a moment, so that the swift current through this small tube should effectually wash out any possible bubbles. The cocks between the gauge and the piezometer were generally kept wide open during an experiment, for I believe that small errors are often introduced by the too close throttling of a gauge to check oscillations, as often practised.

If there happens to be a minute leak between the gauge and the point throttled, then the gauge may be made to read much too low (in these experiments we took good care that there were no such leaks); or if it so happens that the water flows through the orifice in the cock or diaphragm more readily in one direction than in the other, then as the waves or oscillations occur the gauge reads a little too high or a little too low, according to the direction in which the flow happens to be easier.[1]

We had a straight line painted along the plank platform, mentioned above, and stretched our hose out empty along this straight line. On letting the water into the hose, hose of almost every kind expands somewhat in length. For some kind of hose, a piece 100 feet long when empty will be 105 feet long when full of

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[1] It sometimes happens when the passage or the cock leading to a gauge is so closely throttled that a minute speck of dirt may lodge just above this small aperture and act like a check-valve, and if there is much oscillation gives a fictitious reading which is much too high.

A form of minute, leaky check-valve is sometimes applied to hydraulic gauges intended to measure high pressure, as a means of checking an injuriously rapid fall of the gauge; such a device may lead to very erroneous results if there happens to be much oscillation.

water under a pressure of 50 pounds. The result of this elongation is to throw the hose into a serpentine form.

We had three observers — one at each of the pressure-gauges — who observed these gauges each half-minute for the whole duration of an experiment, and one at the measuring-tank. Another assistant managed the turning of the water into or out from the tank, and as we were timing this to tenths of seconds it had to be sharply and quickly done. This was very easily arranged for, as illustrated in Fig. 4. By a very slight deflection of the nozzle to one side the water passed outside of the hood and wasted into the river beyond, and the throwing the jet across the sharp edge of this hood required but an almost inappreciable length of time. As each experiment on friction loss was computed from the average of five to ten independent observations taken simultaneously at the two ends of that length of the hose under experiment, I feel confident that the error in determination of the pressure lost by friction in going from one end to the other of any given sample did not exceed one-half pound, and in general it was much less than this.

Fig. 8 shows the general results of the experiments for as many kinds as could have their curves plotted on this sheet without leading to confusion, and Table No. 1 gives the comparative result of each of the different kinds of hose under experiment. The heliotype illustration (Fig. 7) brings out the reason for the difference in friction loss in various samples in a striking manner.

TABLE No. 1.—Comparative Friction Loss in Various Kinds of Fire Hose. The following comparison is made on the basis of 240 gallons per minute, flowing through hose in each case, which is about the quantity discharged by a $1\frac{1}{8}$-inch smooth nozzle under a pressure of 40 lbs. (indicated) at base of play pipe.

SAMPLE OF HOSE.	Diameter of couplings. Inches.	Average **internal diameter of hose.** Inches.	Mean velocity in hose. Feet per sec.	Increase in length under 50 lbs. average pressure.	Observed **loss of pressure** due friction in each 100 ft. of hose. Hose straightened and length measured under pressure. Lbs. per sq. in.	Percentage corresponding to diam. of hose to be added or subtracted to give friction which would have existed had diam. been exactly 2½ inches.	**Loss of pressure** due friction in each 100 ft. of hose, which this same hose would have shown **had diam. been exactly** 2½ inches. Lbs. per sq. in.
Sample A. **2 1-2 in. Solid Rubber Hose. Boston Woven Hose Co.'s "Extra."** A heavier hose than the next, weighing 25% more. The interior of this hose is free from ridges due threads of fabric, and was intended to be smooth as rubber could be made; being made on a highly polished steel mandrel.	2.52	**2.65**	13.96	¾%	**10.0**	**Add 34%**	**13.4**
Sample B. **2 1-2 in. Solid Rubber Hose. B. W. H. Co.'s "Volunteer."** The interior of this hose is free from ridges due threads of fabric, and very smooth, but was made on a mandrel less highly polished than the last.	2.53	**2.60**	14.50	1½%	**11.5**	**Add 22%**	**14.0**
Sample C. **2 1-2 in. Woven Cotton, Rubber-Lined. B. W. H. Co's "Boston Fire Jacket Hose."** A Regular heavy Fire Department Hose. Rubber lining is thick, and interstices between threads next to rubber lining filled with rubber, so that inner surface remains almost free of ridges under pressure. Hose of same grade as Sample D with addition of a jacket. (See Photograph.)	2.53	**2.47**	16.07	4%	**15.0**	**Deduct 6%**	**14.1**
Sample D. **2 1-2 in. Woven Cotton, Rubber-Lined. B. W. H. Co.'s "O. K. Hose."** A medium-weight unjacketed hose. Rubber lining thicker than Sample K, and interstices between threads next to lining filled with rubber, so that inner surface remains almost free of ridges under pressure. Smoothness and character of lining apparently the same as Sample C. (See Photograph.)	2.47	**2.49**	15.81	5%	**14.5**	**Deduct 2%**	**14.2**
Sample E. **2 1-2 in. Knit Cotton, Rubber-Lined. N. Y. B. & P. Co.'s "Cable No. 2 Hose."** A medium-weight hose. Inner surface medium smooth under pressure. Interstices between threads next lining well filled wth rubber. (See Photograph.)	2.50	**2.68**	13.65	3½%	**11.3**	**Add 42%**	**16.0**
Sample F. **2 1-2 in. Knit Cotton, Rubber-Lined. N. Y. B. & P. Co.'s "Dart Hose."** A cheap, light-weight hose. Interior surface medium smooth.	2.50	**2.50**	15.69	4½%	**16.8**	**0**	**16.8**
Sample G. **2 1-2 in. Knit Cotton, Rubber-Lined. Callahan's "Jacket Hose."** A regular Fire Department Hose. Said to be about the same grade as Sample I with a jacket added.	2.51	**2.60**	14.50	1¾%	**13.9**	**Add 22%**	**17.0**

Sample H. **2 1-2 in. Knit Cotton, Rubber-Lined. Callahan's "Mill Hose."** A rather cheap, light-weight hose. Inside rather rough, due conformation of rubber lining to threads of fabric.	2.51	**2.62**	14.28	3%	**14.4**	**Add 27%**	**18.3**
Sample I. **2 1-2 in. Knit Cotton Rubber-Lined. Callahan's "Volunteer Hose."** A somewhat heavier hose than the last, otherwise apparently the same. (See Photograph.)	2.51	**2.69**	13.55	2½%	**13.5**	**Add 44%**	**19.4**
Sample J. **2 1-2 in. Leather Hose. S. Eastman & Co.'s "Improved."** A leather hose of excellent construction. Laps cut square.	2.50	**2.80**	12.51	2¼%	**12.2**	**Add 76%**	**21.5**
Sample K. **2 1-2 in. Woven Cotton, Rubber-Lined. B. W. H. Co's "Mill Hose."** A cheap hose with medium-thin rubber lining, which under pressure conformed to threads of fabric, thus making interior full of small ridges. (See Photograph.) I infer from comparative appearance of roughness that most other makes of woven "Mill Hose" of same weight would as now made give similar friction, but that they can be improved as illustrated in Sample D.	2.48	**2.53**	15.31	5%	**24.1**	**Add 6%**	**25.5***
Sample L. **2 1-2 in. Unlined Linen Hose.** This was an excellent piece of hose, made by Ross & Turner, and fairly represents friction loss in all ordinary unlined linen hose. (See Photograph.)	2.50	**2.60**	14.50	2½%	**27.2**	**Add 22%**	**33.2**
Sample M. **2 in. Woven Cotton, Rubber-Lined Hose.** Smoothness apparently same as sample D, as judged by inspection of interior at ends of sample.	2.07	**2.12**	21.81	4½%	**33.2**	**Deduct 56%**	**14.6**
Sample N. **2 1-4 in. Linen Hose with 2 in. Couplings.** Fabric same as Sample L. (Value deduced from experiments with 200 gallons per minute flowing in this hose.)	1.95	**2.30**	18.53		**49.5**	**Deduct 34%**	**32.7**

For comparison with above, it may be stated that the loss of pressure due friction in a common, clean, straight wrought-iron pipe coated with tar or asphaltum, and 2½ inches diameter, discharging 240 gallons per minute would be,

computing and interpolating from experiments of Hamilton Smith, Jr., 15.7 lbs. per 100 feet
" " " " " " Henry Darcy, 14.0 " " " " } mean **14.8**

The correction given in the sixth column is based upon the well-known hydraulic rule, that for the same quantity flowing in long pipes of different diameters, but equal smoothness, the friction loss is in inverse proportion to the fifth power of the diameter.

The truth of this rule within the limits of the above experiments is demonstrated very well by a comparison of the last two experiments on samples **M** and **N**, with experiments on samples **C** and **L**.

The figures in the seventh column give the true basis for judging of the relative excellence of a hose as regards smoothness of finish of interior.

* In justice to the Boston Woven Hose Co., the writer desires to state, that since learning the result of these experiments, they have been experimenting and modifying process of manufacture so that interior of mill hose shall retain a smooth surface even under heavy water pressure.

Influence of Smoothness of Surface of Waterway upon Loss of Pressure in Hose.

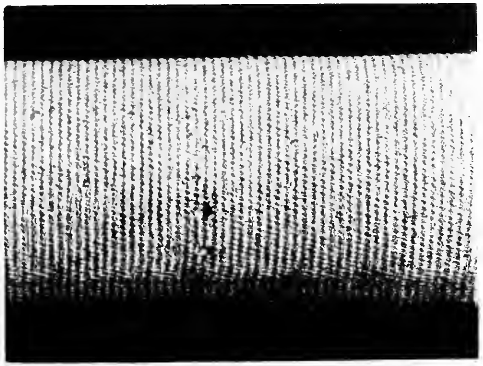
One of the most interesting and valuable points illustrated by these experiments was the very great effect which the smoothness of the inside of hose exerts upon the amount of pressure lost by friction. To determine the exact degree of roughness when the hose was subjected to water-pressure, plaster casts were made of the interior of samples cut from the various kinds. These plaster casts were made by taking a sample from the hose about three feet in length, holding this in a vertical position, and filling it with plaster of Paris, and then instantly screwing on a cap, through which it was connected to a hydrant with a pressure of 50 pounds per square inch. After the plaster had hardened the hose was cut off, leaving the cast as shown in Fig. 7. It was found that casts from some samples of hose were very preceptibly more rough or corrugated than was the hose itself when not subjected to pressure; this being due, of course, to the forcing out of the rubber lining against the threads of the fabric when under pressure.

Much Fire-Hose is Wastefully and Needlessly Rough.

As to the influence of roughness on friction loss, compare sample K with sample C (Fig. 7). Each was a hose of woven cotton fabric, of medium weight, lined with rubber; both were made by the same manufacturer, and were practically alike, with the exception that K was rough on the inside, while C was smooth. Sample K was made, as most "mill hose" and a great part of the "fire department hose" is ordinarily made, namely, with a rather thin rubber lining, which was in calendering permanently roughened by the twill of the cloth used, and which was further roughened and corrugated by its conformation to the threads of the fabric, and still further corrugated when in use, by the rubber lining being forced by the water-pressure into the crevices between the threads, thus giving a surface, as shown by the photograph of the cast K (Fig. 7), which contained corrugations projecting a little more than $\frac{1}{64}$ of an inch.

Sample C and sample D were made by the same maker and of the same material as K, but were made with more care, and the loss of pressure by friction in the hose was found to be but little more than half as great as in the rougher hose. Their rubber lining was calendered smoothly, and was slightly thicker than in sample K, and means were adopted for filling the crevices between the two so that the rubber lining should be well backed up and its inner surface not forced into a corrugated form by the action of the water-pressure. This filling of the crevices between the threads may be attained either by the free use of suitable rubber cement, applied with proper apparatus, or by inserting the rubber lining into the cotton fabric in a semi-plastic partially vulcanized condition, and then completing the vulcanization under such conditions as to permit the rubber before hardening to flow slightly, and thus fill the crevices between the threads.

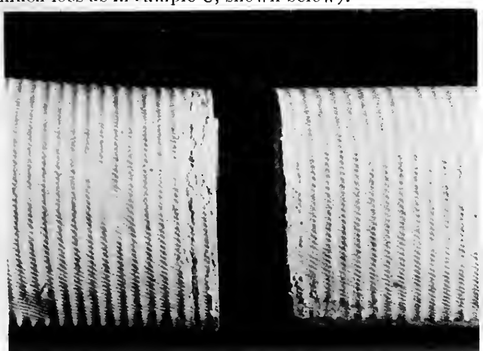
Careful weaving of the hose is also essential if one would obtain smoothness, and consequent low friction loss, for sample E was apparently as smooth as C, except for a waviness of surface, produced apparently by unequal tension



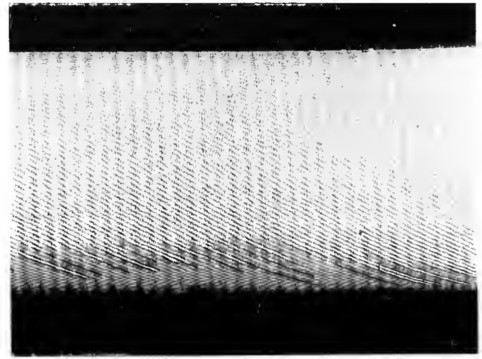
The figures for Linen Hose in tables pages 136 to 167 were based on experiments upon this sampie.

SAMPLE L. **UNLINED LINEN HOSE.**

33.2 **lbs. pressure lost by friction per 100 feet in length** (or $2\frac{1}{2}$ times as much loss as in sample C, shown below).

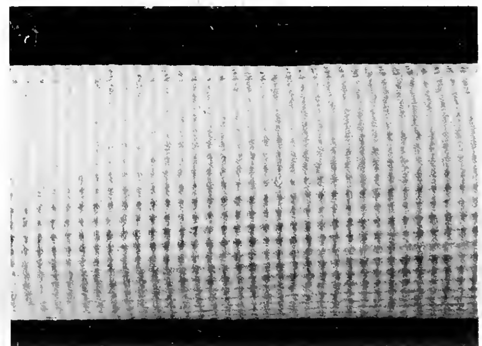


This sample served as basis for the values for "Inferior Rubber-lined cotton hose, inside rough," quoted in tables pages 136 to 167.



SAMPLE X. Not tested for friction. Cast taken to illustrate unnecessary roughness, often caused in process of manufacture.

Fabric and Lining same as C, except that twilled cloth was used in calendering face of rubber lining, thus roughening surface.



Sample K. **WOVEN COTTON, RUBBER-LINED "MILL HOSE."**

(Average depth of corrugations, $\frac{15}{1000}$ to $\frac{2}{100}$ inch.)

25.5 lbs. pressure lost by friction per 100 feet in length of hose (or 80 per cent more loss than in sample D and C, shown below).

Rubber lining was rather thin, and crevices between threads next lining not being well filled, the water pressure caused inner surface to conform to threads of fabric.

This sample served as basis for values for "Ordinary best quality Rubber-lined cotton hose, inside smooth," given in tables pages 136 to 167

Sample C. **WOVEN COTTON, RUBBER-LINED HOSE.**

(Average depth of corrugations, $\frac{1}{1000}$ to $\frac{2}{1000}$ inch.)

14.1 lbs. pressure lost by friction per 100 feet.

Rubber lining slightly thicker than in sample K, and interstices between threads next lining well filled with rubber, so inner surface remained smooth under pressure.

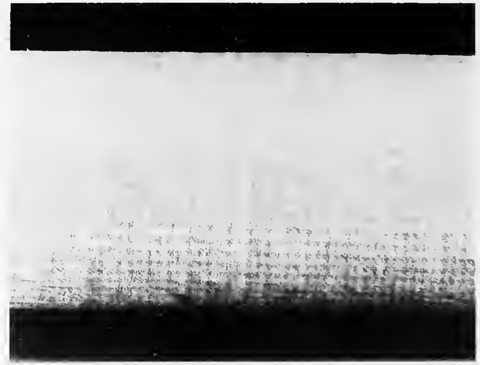
Sample D had same kind of Rubber lining, and gave loss of 14.2 lbs. per 100 feet.

Sample I. **KNIT COTTON, RUBBER-LINED HOSE.**

Interstices between threads next lining not well filled.
Average height of roundabout ridges, about $\frac{1}{100}$ inch.

Average height of ridges which run lengthwise about $\frac{15}{1000}$ inch.

19.4 lbs. pressure lost by friction per 100 feet in length (or 37 per cent more friction loss than in sample C).



Sample E. **KNIT COTTON, RUBBER-LINED HOSE.**

Interstices between threads next lining well filled.

16.0 lbs. pressure lost by friction per 100 feet in length (or 13 per cent more friction loss than in sample C).

PHOTOGRAPHS FROM PLASTER CASTS OF INTERIOR OF FIRE HOSE.

Casts were all taken under a pressure of 50 lbs. per square inch. Photographs are half size of originals.

Losses of pressure given above are those found for 240 gallons per minute (or a good $1\frac{1}{8}$-inch fire stream) flowing in hose exactly $2\frac{1}{2}$ inches in diameter.

FORBES LITH. MFG. CO.

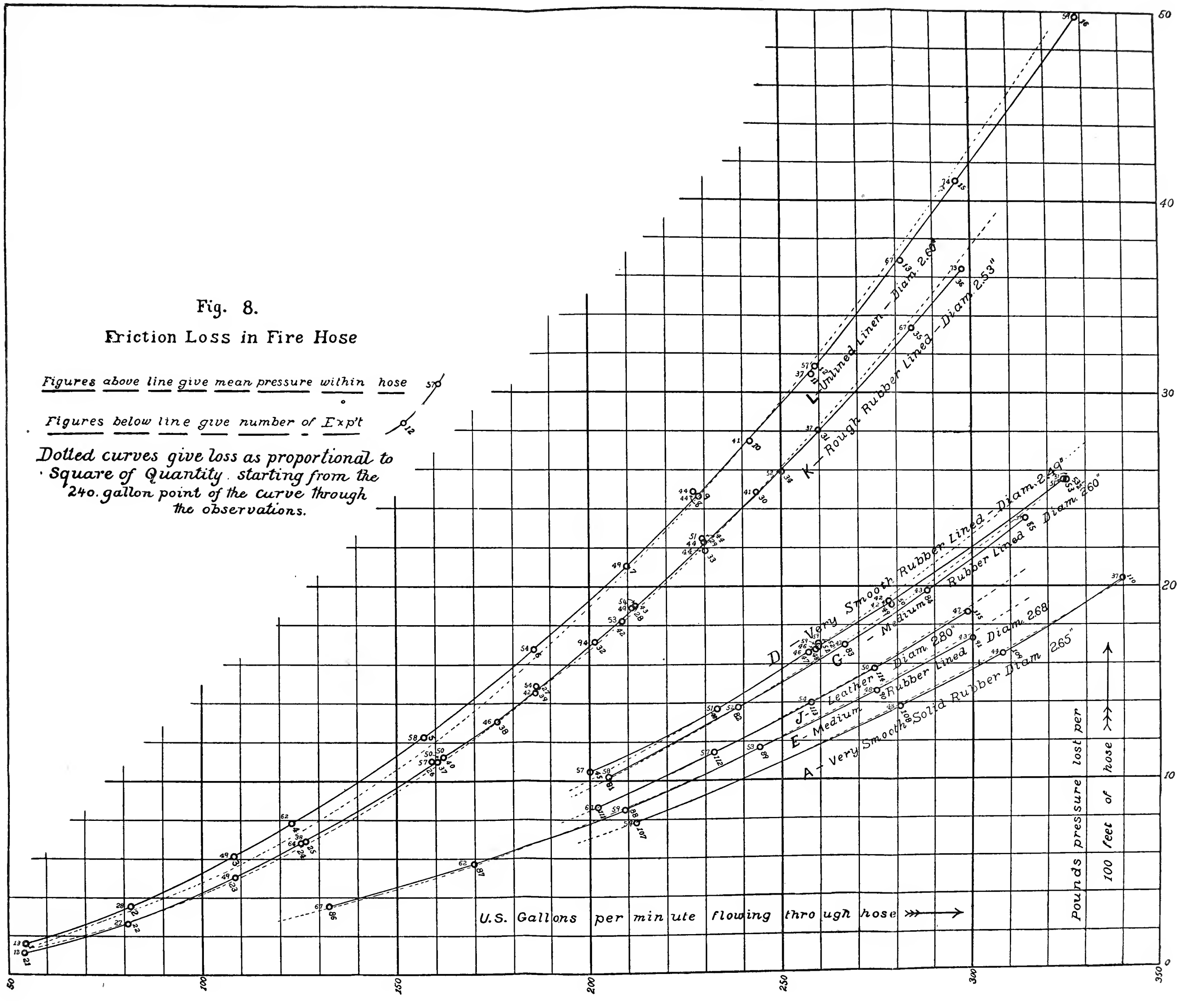


Fig. 8.
Friction Loss in Fire Hose
Figures above line give mean pressure within hose
Figures below line give number of Exp't
Dotted curves give loss as proportional to Square of Quantity starting from the 240 gallon point of the curve through the observations.
L – Unlined Linen – Diam. 2.60"
K – Rough Rubber Lined – Diam. 2.53"
D – Very Smooth Rubber Lined – Diam. 2.49"
G – Medium Rubber Lined – Diam. 2.60"
J – Leather – Diam. 2.80"
E – Medium Rubber Lined – Diam. 2.68
A – Very Smooth Solid Rubber Diam. 2.65"
U.S. Gallons per minute flowing through hose
Pounds pressure lost per 100 feet of hose

in the loom. Had the loom been perfectly adjusted the friction loss would, for the same diameter, have been little, if any, greater than that in C.

Inasmuch as the loss of pressure in a line of 2½-inch hose 1,000 feet long, which is smooth like C, will be no greater than in a line 550 feet long containing such roughness as K, I would most strongly advise fire departments when purchasing hose to specify and insist that its smoothness be fully equal to that of a good, smooth sample to be furnished before the contract is given.

The cost of sample D, in which the friction loss was only about fourteen pounds per 100 feet, with a good 1⅛-inch stream, was only five cents per foot greater than sample K, in which the friction loss was about twenty-five pounds, and I am informed that with the proper arrangements at the factory the extra cost of obtaining a smothness like that of sample C is small.

This point of improving the smoothness is well worthy the attention of all hose-makers. I am led to emphasize it especially from having many times heard hose manufacturers and hose salesmen affirm positively that this little roughness of interior surface had no influence on the loss of water-pressure, that the water next the side lay dead, etc.; which notions, though conclusively proved to be erroneous, as every hydraulic engineer knows, by the experiments of the eminent French engineer, Darcy, thirty-five years ago, are still advocated as an aid to the disposal of imperfect hose.

As to the means by which such small roughness of surface are able to exert such powerful effect upon the friction loss, we may consider that the greatly increased loss is mainly due to the ability of these small projections to set the whole stream to its very centre into a condition of turmoil and minute eddies, just as a single stone at the bottom of a smooth and deep canal is sometimes seen to produce a boiling at the upper surface.

The results given in Table 1 and shown in the photograph of the casts (Fig. 7) also serve as one strong reason for discouraging the use of unlined linen hose in any situation excepting for the stand-pipes inside a building, where the lines of hose are generally short. For it is seen that the gallons per minute delivered and diameter of hose being the same, the loss of pressure by friction in each 100 feet is more than twice as great with the linen hose as with a thoroughly first-class rubber-lined hose.

Effect of Bends or Curves in Line of Hose upon Friction Loss.

This subject was investigated first by carefully measuring the friction loss in a line of hose laid with the ordinary natural sinuosity, and then, without lessening the pressure or interfering with the flow, straightening the same hose out and repeating the experiment. The mean of quite a number of trials with different kinds of hose and with bends of different sharpness was taken, and the experiments agreed fairly well in showing that six per cent. increase in friction loss was a very fair allowance for the effect of any ordinary curvatures and crookedness in which the hose was not cramped or choked off by a sharp angular bend. We might, perhaps, have expected this loss would be greater; still, it must be remembered that the ordinary curves in a line of fire-hose are of longer radius in proportion to diameter than are the longest of "long-turn" pipe-fittings.

Effect of Obstructions at the Coupling.

Throughout the United States an expanded ring-coupling which gives a waterway of the full diameter of the hose is now used by all the best makers. On old hose and on some inferior hose a shank coupling is often used which has its bore $\frac{1}{4}$ inch smaller than the diameter of the hose itself.

We therefore tried some experiments to determine the effect upon the loss of head of inserting a square-edged bushing $\frac{1}{8}$ inch thick at each 50-foot coupling, thus getting a waterway like that in these old-style couplings. It was found that with a 240-gallon stream these increased the loss $\frac{1}{2}$ pound per hundred feet.

In our regular experiments the rubber or leather washers used to make a tight joint at the coupling were all cut out to full size of the $2\frac{1}{2}$-inch coupling. In practice the washers often project into the waterway. We therefore tried the effect of washers projecting in $\frac{1}{8}$ inch, or with a $2\frac{1}{4}$-inch hole, and also tried others projecting $\frac{1}{4}$ inch, or with a 2-inch hole. The increased loss due these small washers, as deduced from these experiments, is given below.

Effect of Small Washers in Hose-Couplings of $2\frac{1}{2}$-inch Bore.

Diameter of hole in washer.	Increased loss of pressure per 100 feet, or for two washers.		
	200 gallons per minute flowing.	240 gallons per minute flowing.	300 gallons per minute flowing.
$2\frac{3}{8}$-inch.	0.20 lbs. per sq. in.	0.30 lbs.	0.46 lbs.
$2\frac{1}{4}$	1.04	1.50	2.34
$2\frac{1}{8}$	2.32	3.34	5.22
2	4.16	5.98	9.34

Influence of Diameter of Hose upon Loss of Pressure by Friction.

The exceedingly great influence of even small differences in diameter upon the friction loss attendant on forcing any fixed number of gallons per minute through a line of hose or small pipe is not generally appreciated. The friction loss varies as the fifth power of the diameter, as engineers express it, and thus if a sample of hose happens to be $2\frac{5}{8}$ instead of $2\frac{1}{2}$ inch, *this $\frac{1}{8}$ inch difference in diameter is sufficient to make twenty-five per cent. difference in the loss of pressure by friction.*

Now, $2\frac{1}{2}$-inch hose is not all just $2\frac{1}{2}$ inches in diameter. The samples of "$2\frac{1}{2}$-inch" upon which I experimented varied all the way from about $2\frac{7}{16}$ to $2\frac{3}{4}$ inches.

Moreover, while under pressure a "woven" hose expands in length, but not in diameter. A knit hose expands not much in length, but chiefly in diameter, and to the extent of about $\frac{1}{16}$ inch for each 50 pounds pressure.

The most convenient way for measuring diameter of inside is to caliper the outside under pressure and mark the spot; then empty the hose, squeeze it together flat between some blocks by some screw-clamps, and thus caliper the thickness of material, which, being deducted from the outside diameter, gives the inside diameter.

SHALL THE STANDARD DIAMETER OF FIRE-HOSE BE CHANGED?

As stated above, the very great difference which a small change in diameter of hose makes upon the loss of pressure due to a given flow is not generally appreciated. For any definite number of gallons per minute flowing, **the loss of pressure is only 40 per cent. as much in a 3-inch hose as it is in a hose exactly 2½ inches in diameter.** For a hose 2⅞ inches in diameter the loss of pressure is just half as much as in a 2½-inch hose; and if we go down to small sizes and make use, as is often done in the protection of factories and of some villages, of hose only 2 inches in diameter, *the loss of pressure in this 2-inch hose is three times as great as it is in a 2½ inch hose.*

That this great difference, although seldom appreciated, is no less a fact, is not only proved by theory, but I have more than once had occasion to demonstrate it experimentally when urging a mill manager to discard his 2-inch hose and refit his premises with hose of larger size. By way of illustrating the principal bearing of this question of the effect of small differences in diameter upon the flow, we might say that if the Boston Woven Hose Co., for instance, should slightly change the diameter of the "two and one-half inch" hose designated as sample C in Table No. 1, increasing it only by $\frac{3}{16}$ of an inch, so it would be of the same size as was the sample of "two and one-half inch hose" marked E, then the loss of pressure per 100 feet of its length would be nearly one-third part less than at present, the smoothness being the same in each case; and as a further illustration, we may say that if some enterprising fire company earnestly desired the prize for distance-playing at a fireman's muster, and would procure some hose 2¾ inches in diameter (if this were like sample D, without a jacket, the difference in apparent size would be so slight that it could hardly be detected), then, with a line of hose 300 feet in length, as is common in such trials, this increase in the waterway would give them a far greater advantage than would any style of fancy nozzle, and would, in fact, send the extreme drops about 20 feet farther.

From strong practical reasons this slightly increasing the diameter of such brands of woven cotton rubber-lined hose as are now made exactly 2½ inches is well worthy of consideration. The bore of the coupling could continue 2½ inches, as at present; and even though the hose were, as a regular thing, made 2¾ inches in diameter, the loss from this smaller size of coupling, coming as it does only once in 50 feet, would be almost unappreciable, providing the reduction from 2¾ to 2½ inches were made gradual, on a taper, with corner at end of taper smoothly rounded off, instead of by a square-cornered shoulder. This can easily be provided for, especially by increasing length of coupling a little, and not add more than 25 cents to the cost of the couplings.

The present size of fire-hose was established many years ago, in the days of the old hand-engines, or before steam fire-engines had attained their present perfection and power. This was also before the Portland fire, the Boston fire, the Chicago fire, and numerous extensive factory fires had given costly object-lessons as to the value of large-sized streams. For a wooden dwelling, or for a fire in an ordinary small-sized store, or for any fire in its incipiency, — in fact, for nineteen out of twenty of the fires to which the department of the ordinary city responds in the course of a year, — a jet from even a ¾-inch nozzle may be

large enough; but once let a fire get under full headway, and the demand for something larger is imperative.

The water from a small stream falling in the condition of finely divided spray is evaporated and turned into steam almost before reaching the fire, while a 1¼-inch jet from a smooth nozzle in the first place sprays less, and, in the second place, contains a sufficient volume of water, so that even though half be evaporated in the flames, there is a body left which can go through the burning gases and strike the coals themselves.

A fire is never put out by playing into the flames. It is only put out by cooling off the burning coals themselves by the bodily application of water to their surfaces; yet this simple and fundamental fact appears to be not nearly so widely understood as it should be.

I have been an eye-witness of quite a number of very extensive fires, and each time I have been struck with the general feebleness of a large proportion of the streams, and conversely I have seen many instances to prove that a fire must be an exceedingly hot one when a good, stiff, clean 1¼-inch jet, fairly delivered in its midst, will not leave a black mark. Occasionally, of course, fires obtain such headway in undivided structures of large area that even a stream of this size is evaporated; but I have studied this matter carefully as an eye-witness in instances enough to convince me that the reason we so often hear that the streams proved unavailing, is that a thoroughly first-class, large-sized stream is so comparatively rare; and with the ordinary range of water-pressure at steamer it is useless to think of playing a stiff 1¼-inch stream [1] through more than 500 feet of fire-hose of average smoothness, as generally made to-day, so long as diameter is not greater than 2½ inches. (As already stated, some few makers now make their so-called 2½-inch hose actually almost 2¾ inches in diameter, and gain greatly in the saving of friction.)

The 2¾-inch hose mentioned above, fitted with couplings of 2½-inch bore and the present screw, so as to be absolutely interchangeable, would, with the same pressure at the hydrant or steamer, give a stream at the end of 1,000 feet of hose equally as large and strong as can be obtained from a line of hose just 2½ inches in diameter and only 650 feet long.

As I said above, the present hose will answer well enough for nineteen fires out of twenty, and perhaps for even a larger proportion, but when a fire of great magnitude occurs, ordinary hose and nozzles are not at all suited to cope with it, mainly by reason of the great loss of pressure between the engine and the nozzle.

The only possible objections to this larger hose are, first, the increased weight to handle. This cannot be considered insurmountable in view of the fact that some of the knit hose already in use is, when expanded by pressure, of nearly 2¾ inches in size, and is handled without difficulty. Moreover, a length or two of light unjacketed 2½-inch hose could be used next the nozzle for inside work or work upon ladders, for my proposition is that all the hose, large and small, have interchangeable couplings. The second objection is the reduced bursting strength due to the larger diameter. This, with the fabric remaining just the same, would amount to only ten per cent., and any fabric now testing at 500 pounds on a 2½-inch diameter would stand 450 pounds on a 2¾-inch. In fact, the

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[1] Forty or fifty lbs. nozzle-pressure.

best 2½-inch jacketed fabrics of to-day are amply strong enough to stand a 3-inch diameter. In general, however, the saving in pressure lost by friction would enable the working pressure at engine to be less, and thus make a saving in working strain, offsetting the weakening by increased diameter. I incline very strongly to the opinion that it will be found best not to rest content with a 2¾-inch diameter, but to go far enough, while we are about it, and adopt a 3-inch diameter as the standard for fire-hose.

Still, until practical experience has been had in the manipulation of this hose, and until it is proved with certainty that it is not too large and cumbersome for regular use, I would adhere to the interchangeable coupling with the standard thread and of 2½-inch bore.

There is no greater evil than getting lots of hose into a fire department which are not perfectly interchangeable. A computation which I have made shows that with these couplings of 2½-inch waterway, located 50 feet apart, and with their bore ½ inch less than diameter of hose, the loss of pressure due to the small area of these couplings *would offset only one-twentieth part of the gain coming from the larger size of the 3-inch hose*, providing, as already stated, the reduction in the diameter of the coupling at the screw from 3 inch to 2½ inches was made with a taper, and not with a sharp, square shoulder.

This advantage of 3-inch hose is not wholly a matter of theory. I am told that it has been reduced to practice with the most gratifying results. Over a year ago I presented the facts, much as I have just presented them, to the treasurer of the Eureka Fire Hose Company, of New York. I am pleased to say that the Eureka Company have taken action in this matter, and have furnished several thousand feet of such hose to various fire departments, and I am told that it is not found too heavy to handle, and that its operation is in every way gratifying.

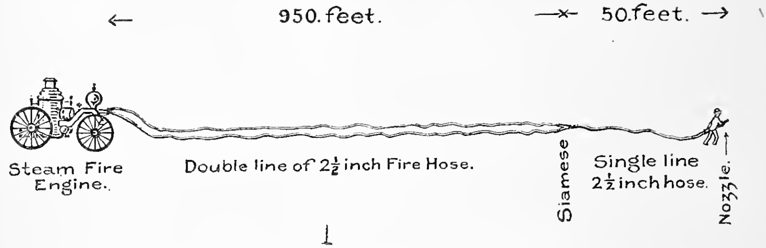
I am well aware that the National Association of Fire Engineers considered this matter at their last meeting and decided adversely to it, but I feel that this decision must have been reached without a proper understanding and consideration of all the facts in the case. I have considered the whole matter in the light of these experiments, — considered it as I went around "within the lines" at the fierce and rapid fire which burned the Lowell Railroad storehouse, and considered it again as I went from point to point in the heat of the fire at Lynn a fortnight ago, and I am still just as confident as ever of the merits of the proposed change.

With this 3-inch hose a 1¼-inch stream can be played at the end of a line 1,200 feet long just as powerful as can now be played with the same engine-pressure at the end of a line 500 feet long. And a stiff 1½-inch stream with lines of moderate length from a first-class steamer would involve no great difficulty.

Double Lines of Hose for Long Distances.

While we are on this subject I may also add a word to the effect that at many fires which I have attended it is almost agonizing to see the ignorance displayed by the engine captains as to the friction loss in hose. It is also a matter of great regret to see how seldom a Siamese coupling is used to connect two lines of hose *from one steamer* into a single line at a point 50 or 100 feet back from the nozzle, in cases where the distance from the steamer to the seat of the fire is great.

Fig. 24.



I refer now not to the use made of the Siamese for connecting the water thrown by two steamers into a single large and powerful stream, but rather to its use in reducing the friction loss between any one steamer and the one nozzle which it is supplying. When we thus carry the water through *two lines* of hose instead of through a single line of hose, the velocity of the water is, of course, but *half as great* in each of the two lines. The result of this is that the *loss of pressure is only one-fourth as much* as in the first case, and if the steamer stands 1,000 feet away from the Siamese, we have by the double line of hose practically reduced this distance to 250 feet. This is fact as well as theory, as you can readily demonstrate by trying the simple experiment for yourselves.

Or if, for convenience of working, the Siamese is placed 50 feet back from the nozzle, as shown in Fig. 24, then, although the nozzle is a thousand feet from the steamer, the loss by friction is so lessened by the double line of hose that with the same steamer-pressure a jet will be thrown with exactly the same force as though steamer were only 287 feet from a nozzle on a single line of hose.[1]

At other fires I have seen two steam fire-engines laboring heavily to do what one steamer and a double line of hose could have done much better.

I refer to one steamer pumping into the second steamer, and the second steamer pumping on to the fire.

There are many good practical firemen who will say it is contrary to common practice and to common sense to claim that this Siamese and the double line of hose will do more work than the second steamer; but let them try the experiment and see. We can also prove it by a simple little computation.

Suppose the fire to be 1,800 feet away from the nearest good source of water. Suppose the fire so large that we earnestly desire a good $1\frac{1}{8}$-inch stream. This requires 240 gallons per minute.

1st case. — Two steamers and a single line of hose. By Table A, No. 4, p. 143, it may be seen that to barely deliver this 240 gallons per minute through 1,000 feet of the best $2\frac{1}{2}$-inch hose into the suction of the second steamer will require a water-pressure of 130 pounds at the first steamer. And the second steamer must

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[1] This is proved thus: For the 950 feet of double line each stream will move with half velocity, and therefore the loss by friction will be one-quarter as great as though all this water were going through a single line of hose $\frac{950}{4} = 237$ feet. To this add the 50 feet single line, and we have 287 feet.

show a water-pressure of 145 pounds to play this good 1⅛-inch stream on the fire through 800 feet of hose and get the necessary 40 pounds pressure at the nozzle.

We thus have to tax two powerful steamers to their utmost to get a single good 1⅛-inch stream on the fire.

2d case. — For the same situation take a double line of hose 1,750 feet long, bring the two together by a Siamese, and to this attach a single line of hose 50 feet long leading to the nozzle. To give our stream pressure 40 lbs. at the nozzle we must, 50 feet back from the nozzle, at the Siamese, have a pressure of 47 pounds, and thence for the 1,750 feet back to the steamer the 120 gallons per minute flowing in each branch will cause only $\frac{13}{4} = 3\frac{1}{4}$ pounds friction loss per hundred feet, or 57 pounds in all, which added to the 47 gives 104 pounds at the steamer.

In the first case, with two steamers, one playing into the other, the average steamer-pressure was 137½ pounds.

In the first case the entire labor of one steamer and one-fifth of the labor of the other are absorbed in useless friction, which is wholly avoided by the extra piece of hose. And repeating the idea in still other words, by way of still more emphasis on this overlooked but valuable point, the simple expedient of dividing the stream into two parts, and uniting them again by a Siamese a convenient distance back from the nozzle, is more efficient than an extra steamer, and sets the second steamer free for an additional stream on the fire.

At Lynn the other day I saw in one case a powerful steamer attempting to play its stream through 2,000 feet of hose.[1]

I saw another steamer trying to pump through 1,500 feet of hose, and the streams reached about as high as a small boy could propel water through a squirt-gun. Moreover, it has been my duty to investigate a number of mill fires where the department has complained of the "unaccountable failure and loss of pressure in the water supply," that "somehow it failed to give its usual force," when the only reason in the world was that whereas on dress parade they were accustomed to test with *50 or 100 feet* of hose, they were obliged in their time of danger to use more lines of hose and to play through *several hundred feet of hose.*

[1] I counted the lengths myself, and then got a friend to count them independently, and there were either forty or forty-one fifty-foot lengths.

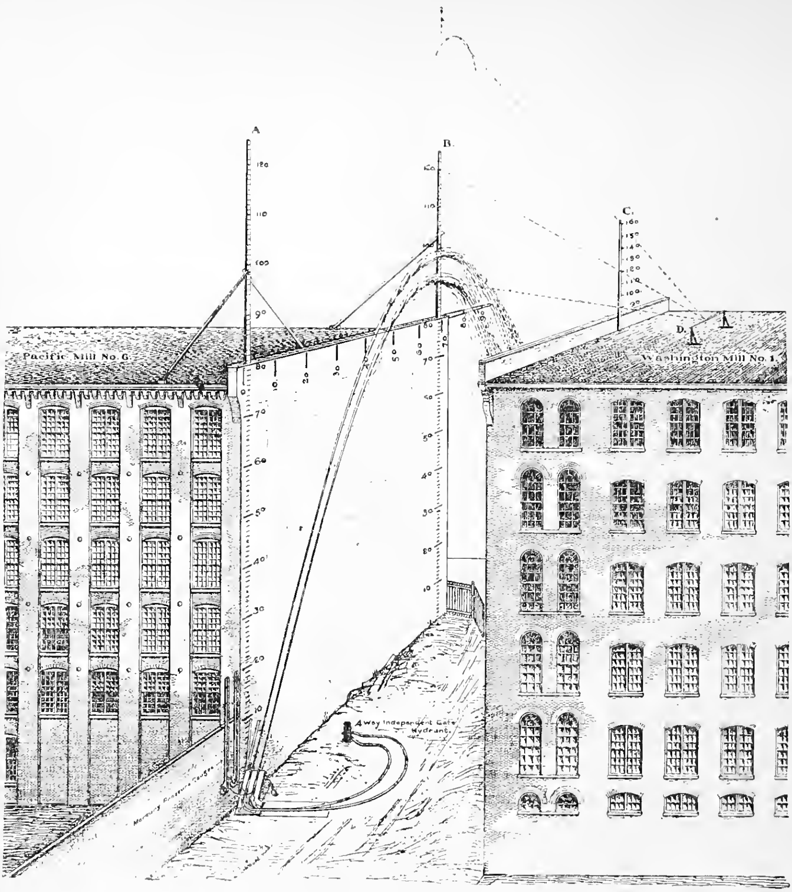


FIG. 9. — EXPERIMENTS ON FIRE STREAMS AT HIGH ELEVATIONS.

The final experiments on which tables for height of jets are based were made at this site, but in these only one nozzle was used at a time.

The above sketch illustrates experiments to determine which of two nozzles (ring or smooth, for instance) was the better, or would throw stream highest and with the least spraying, — pressure at base of each play-pipe being the same. For this the two 50-feet lines of hose leading to play-pipes were of same kind; bends in hose at base of play-pipe were carefully laid flat on the inclined platform, as shown, and clamped between blocks jig-sawed from 3-in. plank, so each hose lay in flat curve of 3 feet radius. One to two feet of hose next base of play-pipe was straight.

The masts, A and B, were graduated in feet, and reached to a height of 124 feet above nozzle. Below the masts, scales, made of strips of wood strung on heavy steel wire, marked each foot in height along face of wall.

Horizontal distances from end of nozzle were marked by wooden rods 10 feet apart, nailed to top of wall, as shown.

When height of jet was more than 130 feet, the mast, C, and sighting-bar, D, were used in estimating height, proper allowance being made for parallax.

The play-pipes and their supporting platform could be set at any angle of elevation required, and securely clamped.

End of nozzle was set level with zero of mercury pressure-gauges and zero of scale of height.

An assistant regulated pressure to within one-tenth of a pound by valves at hydrant, and, when all was ready, one observer read the mercury gauges each half-minute, while another observed and noted height and characteristics of jet, as seen from the mill roofs.

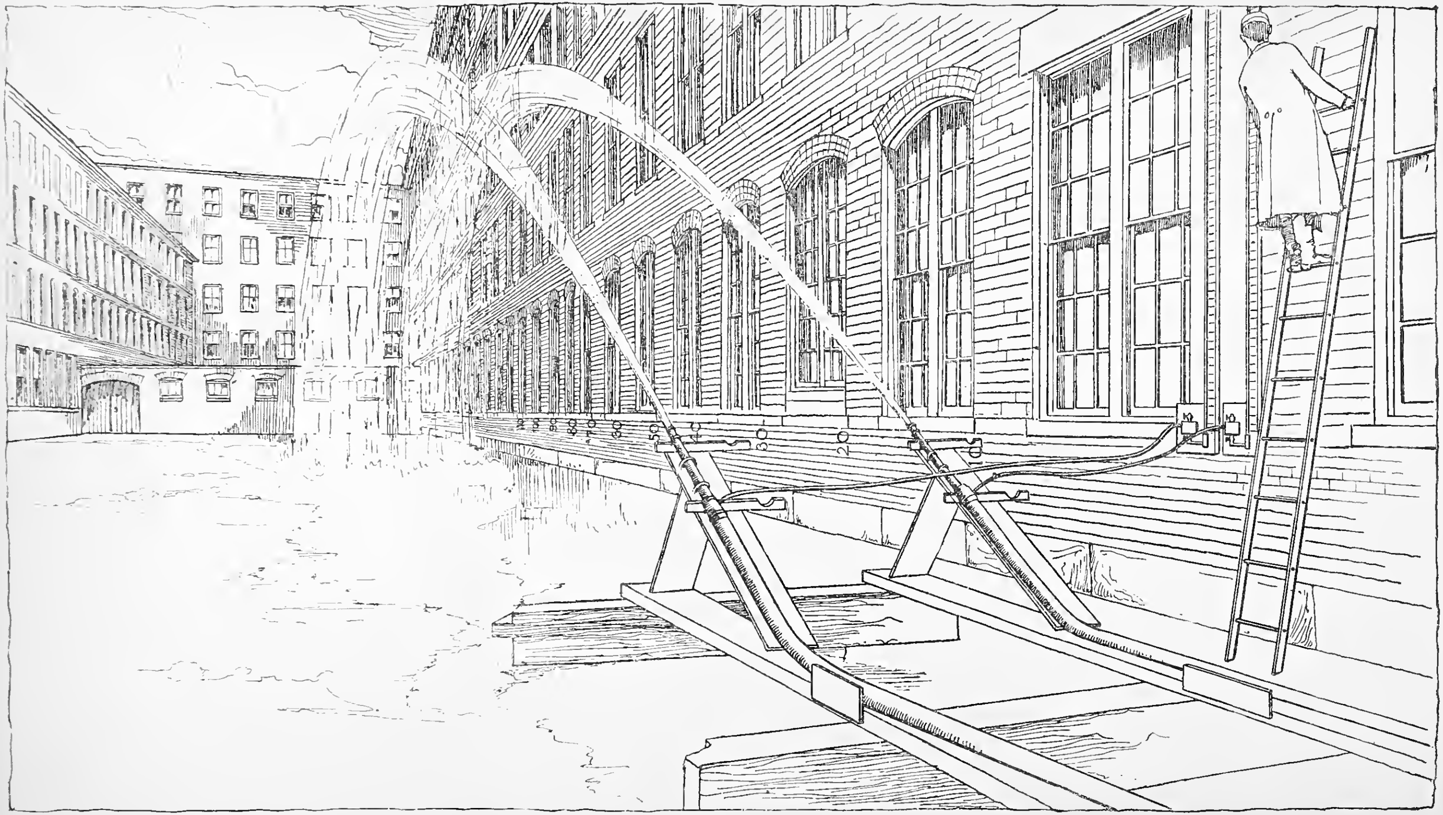


FIG. 10.

Experiments on Jets.

Fig. No. 9 and Fig. No. 10 show the general arrangement of the apparatus for the experiment on jets. It will be seen that we had unusually convenient situations for making these experiments accurate. The difficulty found was not of trouble with apparatus, but was of trouble with air currents or wind. It was very difficult to find a time when air was so still as not to influence the results. For six weeks, while engaged on other experiments here described, we kept the apparatus handy, and watched for the smoke from the neighboring chimneys to rise vertically. Several times we started in and found the effect of the wind so evident that we stopped. It was found that a moderate summer afternoon zephyr would affect the height or the reach of the extreme drops fully ten per cent., and there is no doubt whatever but that the remarkable records sometimes made at firemen's musters are due to a favoring gust of wind far more than to the perfection of their "fancy nozzle."

The detailed results are given in the paper already referred to, and so here we need only say that these experiments furnished the basis for the heights stated in the practical tables at end of paper. Not only were the previously recorded experiments on height of jets very few indeed, but they gave only the height and distance of the extreme drops. This reach of extreme drops is almost worthless information for the firemen, and as given in pump catalogues has worked deception and false sense of security to the purchaser of pumps.

Height and Distance as a Good Fire Stream.

I gave much attention and earnest effort in trying to determine the limiting distance as a good practical fire stream under the several pressures. This point is not sharply defined. It is hard and puzzling to draw the line and say to a foot or even to five feet just where the stream ceases to be good. Some experienced firemen would no doubt class it as good at a point ten per cent farther or higher than I did, but I kept the effect of a moderate wind in mind, and also took the distance at a point where the stream had not lost its continuity by breaking into a shower of spray.

The jet diagram (Fig. 10) gives this information about the height and distance reached by jets in a very practical and convenient form.

Comparative Efficiency of Various Kinds of Nozzles.

The figures Nos. 9 and 10 illustrate the conditions under which the comparisons were made so fully as to call for little further comment. The nozzles compared were tested side by side for distance, as per Fig. 10, and for height, as per Fig. 9, under conditions as nearly absolutely identical as they could be made, and I believe them to have been by far the most accurate set of comparative experiments on this subject ever made. I say this in the effort to carry conviction to the hearts of the ring-nozzle advocates.

Ring Nozzles *vs.* Smooth Nozzles.

The first point to be settled was, of course, the oft-argued question of ring nozzles *versus* smooth nozzles. These, with both "undercut ring" and "square ring," were compared in various sizes, and finally I constructed a ring nozzle

with an orifice of such size that under a given pressure it discharged the same number of gallons per minute as a $1\frac{1}{8}$-inch smooth conical nozzle.

These tests showed in the most positive and convincing manner that either the common form or the undercut form of the *ring nozzle does not possess the slightest superiority over the smooth nozzle.* The difference between the two was, however, small, and in general amounted to about two per cent. in favor of the smooth nozzle. It may be well to stop a moment and explain to some who are not firemen just what is meant by a "ring nozzle." The following three figures make the distinction plain. The "ring nozzle" has a sharp corner or contraction close to the end, and some people suppose this cuts off or holds back the more disturbed part of the current close to the walls of play-pipe.

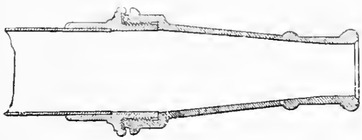


FIG. 11. — SMOOTH NOZZLE.

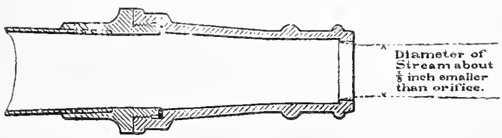


FIG. 12. — SQUARE RING.

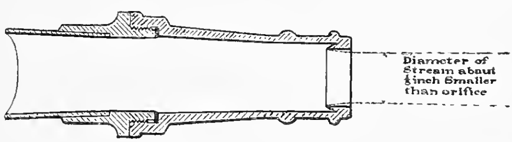


FIG. 13. — UNDERCUT RING.

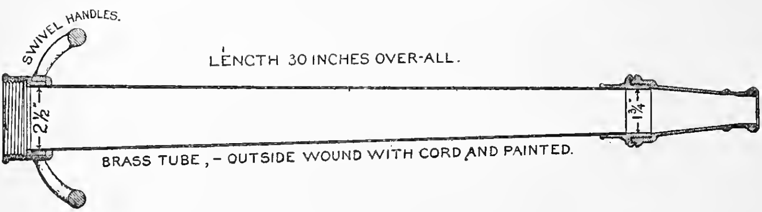
We find so many ring nozzles in use, and find their merits so stoutly maintained, that I will state that a final demonstration of the general range of these experiments, at which two of the most eminent hydraulic engineers of the time, Mr. James B. Francis and Mr. Clemens Herschel, did me the honor of their presence, and at which Mr. Salisbury, member of this society, and also the full corps of Inspectors of the Associated Mutual Insurance Companies, a body of men who in the regular course of their duties pass critical judgment upon thousands of fire-streams in the course of a year, were present. *I believe all present to have been satisfied that the ring nozzle was in no way superior to the smooth.* Examining both jets at points within a dozen feet of the nozzle, one had just as much of that mythical "surface smooth as a glass rod" as the other.

The only advantage of the ring nozzle is that it makes a show of playing a larger stream than is the fact. The ring makes the stream contract to about an eighth of an inch smaller than the size of the hose. It may afford satisfaction to the builder or the engineer of a steamer to say he is playing a 1⅛-inch stream, when actually throwing only as much water as will go through a 1-inch smooth nozzle; but the apparent benefit as to distance reached which sometimes actually comes from the use of a ring nozzle is easily explained, and is just the same as would be secured by using a good smooth nozzle of ⅛-inch smaller diameter. The gallons per minute thrown being less, the loss of pressure by friction in the hose is less, and therefore the greater pressure available at base of nozzle impels the stream a greater distance.

Not only were comparisons made with ring nozzles, but comparative tests of various other kinds of nozzles were made. The forms experimented on, and their effect and relative value, are detailed in my paper before the Civil Engineers. The whole result may be summed up by saying that *nothing was found which was in the slightest degree superior in projecting qualities to a good, plain, smooth, conical nozzle like that shown in Fig. 21.*[1] This result was contrary to

[1] The cone must converge with a good degree of taper, like Fig. 21; for on testing a conical nozzle known in the trade sometimes as a "screw nozzle" and very commonly sold, this was found about six per cent. inferior in projecting power, due to the too small waterway in throat of play-pipe, next to where the nozzle or tip screws on.

STANDARD NOZZLE FOR FACTORY USE.



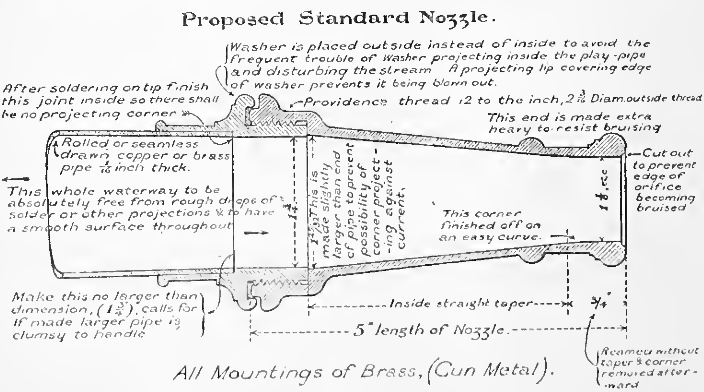


FIG. 21.

my anticipation, for I had confidently expected to find some other form that would give a more polished, smooth, solid, far-reaching stream.

I may here record that though I have looked for it a thousand times, I have never yet seen a stream issuing under a pressure higher than twenty pounds at nozzle which did have a clean, glassy, transparent surface for any considerable distance away from the nozzle. A careful and minute examination will show that under a pressure of forty pounds, even at only an inch distance from the smoothest and best nozzles, minute drops are beginning to tear themselves away from the main stream, thus giving the jet a roughened appearance like ground glass.

With a view to getting a better class of play-pipe and nozzle into general use in our mills, I designed the nozzle shown in Fig. 21 as one result of the above experiments, and furnished blue-prints of the working-drawings to about all of the leading makers of fire apparatus, so that now it is a matter of regular stock to be found with most dealers, and is known in the market as the "Underwriter pipe."

There is nothing specially novel about it, and there is no patent upon any part of it. I merely combined those elements which had been found to give the best results. Other high-grade nozzles can be found in the market or in use which will probably give just about as good results, but the experiments described above make me firm in the belief that there is nothing now made that will throw any better stream than this will, and if any of you happen to want a nozzle for accurately gauging up to 250 or 300 gallons per minute, this, in connection with a piezometer like Fig. 1 screwed into its butt-end, will fill the bill.

With firemen a flexible play-pipe tapering but little if any up to a point within a foot from the end, is at the present time more popular than a metal pipe. I tested one of these, and found that if properly made with a smooth interior, and with its cone on a smooth regular taper, it would throw very nearly as well as Fig. 21; but the Underwriter pipe was, as stated above, designed for mill use, where it may be called into play after standing twenty years, while flexible rubber or leather fabrics are liable to fail from the rotting of the rubber when no more than five years old.

I include below cuts of a few of the kinds of nozzles tried, a glance at which may be of a little interest to some of you.

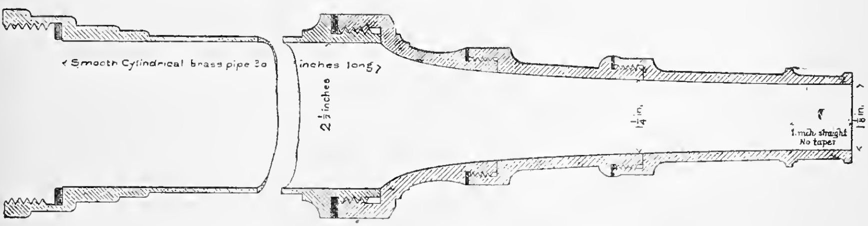


FIG. 14. — 1⅛-INCH "UNIFORM ACCELERATION" NOZZLE.

It has been thought by good authorities that there was good theoretical ground for expecting the above nozzle to give superior results. Careful comparison in

the manner of Figs. 9 and 10 showed that there was no appreciable difference either in reach of jet or in amount of spraying between this nozzle and that with straight taper like Figs. 15 or 21; and thus this elaborate form was proved to have no advantage over the plain cone with straight taper.

Value of the Non-Tapering Cylindrical Part at End of Nozzle.

Nozzles of these two forms next shown were tested side by side on similar play-pipes. C was like A, except that about an inch had been cut off close to end of taper.

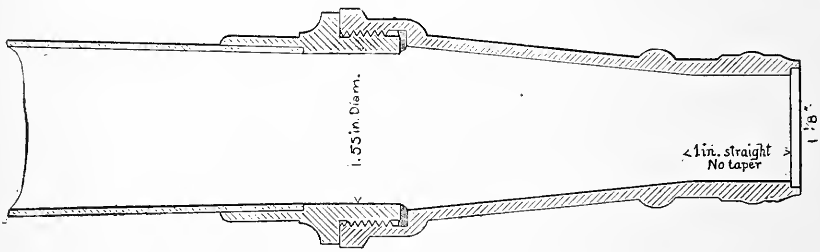
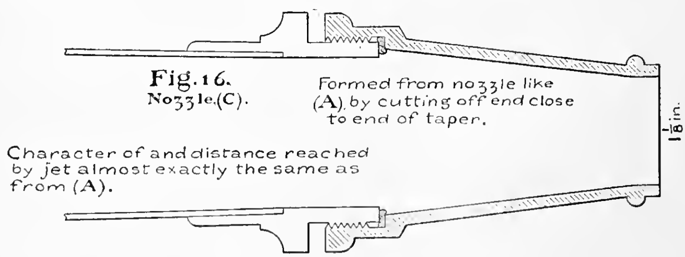
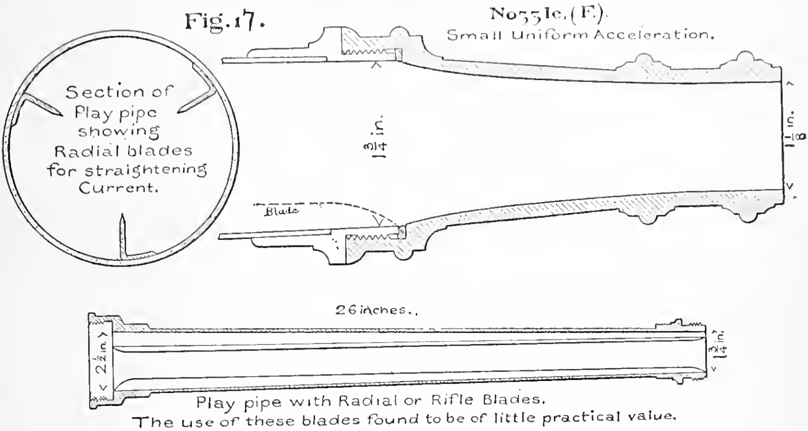


Fig. 15. — Nozzle A.



There was no perceptible difference in the two jets at 50 pounds or at 100 pounds pressure, showing the cylindrical part at end of cone is not really needed.

NOZZLE WITH RADIAL BLADES FOR STRAIGHTENING CURRENT.

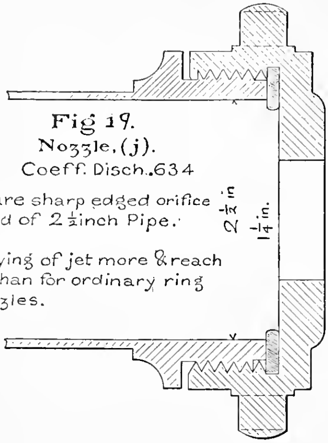


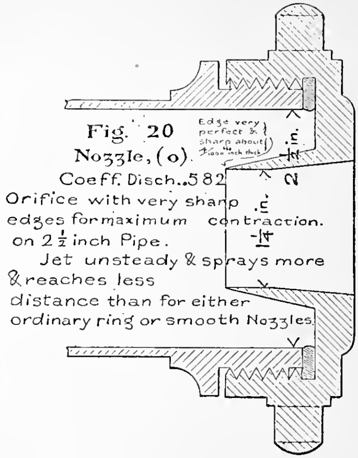
No difference between this and the plain cone could be detected, and the use of the blades was found to be of little value.

Another style of play-pipe (Silsby), in which the three radial blades extended to centre, was tried, and its blades were found to give it no advantage over the smooth cone, so long as hose lay in a plane, vertical curve. If, however, both lines of hose were put into a spiral corkscrew-like form, the jet from the plain pipe fell short two to five per cent. by reason of the twist in the water, while that from the pipe with the blades held its own. In a Siamese jet, where three lines of hose were united into one, from the play-pipe immediately up-stream, these blades, like Fig. 18, were found to aid materially by removing twisting of current and keeping stream from spraying.

FIG. 18.

The following were also included :—





Velocity in Different Parts of Jet.

There is but one other set of experiments to which I will call your attention, and I will do this very briefly. These were upon the comparative velocity in different parts of the stream just after it left the nozzle,—or "distribution of velocity," as it is called. By a delicate instrument, on the principle known among hydraulic engineers as that of "Pitot's tube," the pressure of the current in different parts of the stream was measured, and from this the velocity computed. These are the first investigations on record of this kind with regard to jets, and you may find the results rather curious.

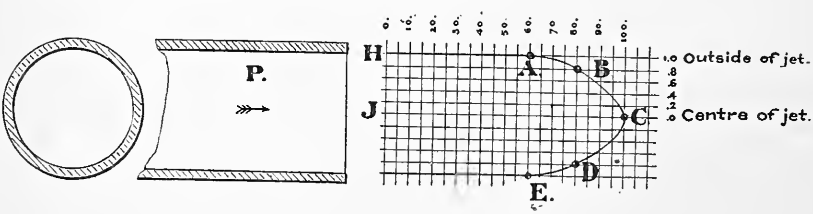


Fig. 22.

Let P be a straight, cylindrical pipe 5 feet or more long, from which the water is being discharged in a forcible jet. It was found that for a jet from a pipe like this, experimented on at a point close to the nozzle, the velocity at centre was very much the greatest, and that the velocity grew less rapidly as we approached the side. Thus, if we represent the velocity in the centre of the jet by the distance J C, then the velocity close to the side of the jet will be represented by the distance H A, and the curve, A B C D E, will represent the velocity at the different distances from the centre. Thus we found the velocity close to

the side to be only 60 per cent. as great as the velocity in the centre of jet. This, be it remembered, is for a straight, uniform pipe.

With a rapidly converging nozzle the relation was very different. Thus, for the standard conical nozzle, similar to Fig. 21, the curve of distribution of velocities was as shown below.

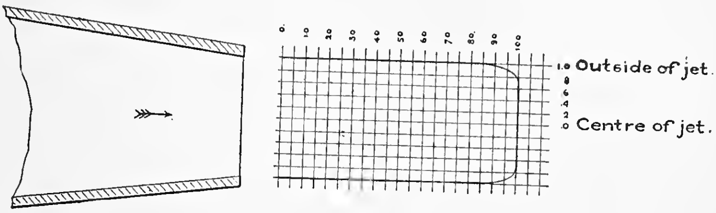


Fig. 23.

For three-quarters of the way from centre to circumference the velocity of all the fluid threads is the same, and is found to be just equal to the theoretical velocity due to the pressure. Within a short distance of outer surface of jet there is a little retardation, however, coming from the friction of the walls of the nozzle; and, by careful measurement, the total amount of this retardation near the sides is found to just equal the difference between the theoretical discharge and the actual discharge, or to fully account for the "coefficient of discharge," as we call it in hydraulics.

It was found that with the "sawed-off" nozzle (Fig. 16) this retardation was a trifle less than with the nozzle of Fig. 15, while with the sharp reëntering knife-edge of Fig. 20, the retardation at side was still a little less, but not very materially different from that found to exist for the nozzle shown in Fig. 15 or 21.

Proper Allowance for a Good Fire Stream.

Before closing the subject I would like to say a few words about a question which we hear often agitated among water-works engineers and mill managers; viz., How many gallons per minute is a fair allowance for a good fire stream?

We have statements all the way from 175 gallons per minute up, and these estimates have been made in all sorts of ways, such as by attaching a meter to a hose stream, or by dividing up the water-works pump record by the number of streams supposed to have been thrown during a fire.

The point I would make is this: The needs of the present and the future should have a voice in answering this rather than the mere record of gallons thrown on certain past occasions. The problem should be attacked wholly from the two following standpoints: —

1st. What diameter of jet, within reach of one steamer and one line of hose, is practically the best?

2d. What pressure at the nozzle can the pipe-men handle to best advantage?

The argument rests wholly with these two questions. These two questions once settled, then the tables and experiments which I have presented give a complete answer.

To cite some great fire of the past, and say that the counters on the water-works pumping-engine indicated 1,750 gallons per minute while ten streams were being thrown, and therefore 175 gallons per minute is a proper allowance for a good practical fire stream, is by no means a complete answer, until it has first been shown whether these were really *good* practical fire streams.

Let us illuminate this question a little by the light of the Lynn fire. Going from point to point, I carefully looked at stream after stream. Many of them could not rise to a third-story window, or reach far enough so firemen could be safe from falling walls or sheltered from scorching heat, and still deliver water to the critical point. *Not one in four could be called a first-class fire stream. Our apparatus is planned for the ordinary fire, not for the extraordinary fire.*

Why are the streams so often feeble?

For the moment, and in your presence, we will assume that the water works are all right;[1] the steamer *is* all right; there is no trouble about getting a nozzle which is all right. *The trouble is generally in the hose*, which may be so long, so small, or so rough, that it will not carry the water so fast as the nozzle can use it, or as the steamer can furnish it.

In a great fire like that at Lynn or at Boston a 1¼-inch stream from a smooth nozzle should be the smallest used. With 30 pounds at the nozzle this will go 50 to 60 feet above the pavement in good, solid form, ready for business, and require *265 gallons per minute.* With 50 pounds at the nozzle two or three good men can still handle it easily, and it will rise at a good working angle 70 to 80 feet above the pavement, still in compact form, not a mere spray, all ready to flash into steam, — and *this calls for 347 gallons per minute.* And sometimes a 1⅜ or even a 1½ inch stream will, after we get better hose, be called into use.

Those, gentlemen, are the streams with which the fireman of the future is going to work when he has serious business in hand.

After the great Boston fire, with its cost of seventy million dollars, they added an eighth of an inch to their nozzles; and gradually, gentlemen, by object-lessons, at a cost of many thousand dollars apiece, the firemen will get educated to have such hose and their apparatus so arranged that they can instantly, if serious occasion demands, throw a good stiff 1¼-inch stream, even though steamer be 500 or 1,000 feet away from the hosemen; and you, gentlemen, have got to fix your water mains so as to give the water to do it with.

Although we should be prepared to supply any particular stream with 300 or 350 gallons, yet even at a great fire, at any given moment, some steamers will be stopped, some hosemen will be along the skirmish line at work with smaller streams, wetting down roofs and washing incipient flames off from wooden cornices and mansards; and taking all these things into account, I believe that we ought, in our computations and estimates for water supply, to provide at the very least an average of *250 gallons per minute for each stream* in the business centre of a city, or round about any extensive factory. In a dwelling-house region less will suffice.

Two hundred and fifty gallons per minute for each first-class hose-stream is

---

[1] At Lynn, in the westerly part of the burned district the steamers had plenty of water in the pipes from which they drew, but on the easterly or leeward side some of the steamers located on a slight rise of ground were sucking at almost empty pipes.

the figure which I regularly use in my estimates for designing or proportioning the pumps and pipes for the protection of large factories.

EFFECT OF JETS OF WATER ON FIERCE FIRES.

I have heard much said about water having no effect on a fierce fire. I have tried earnestly to watch its effect on some three or four fierce fires. I believe there is once in a very great while a fire which would instantly turn a $1\frac{1}{4}$-inch stream into steam as it passed through the flames (and then the $1\frac{3}{4}$-inch or the 2-inch Siamese stream may come into action with great effect, if steamers can be spared from surrounding property), but I believe the frequency of such occurrences is greatly exaggerated, and that the verdict, "The streams seemed to have no effect," comes more than nine times out of ten from the streams being feeble.

I have seen a good, stiff $1\frac{1}{4}$-inch stream make a black mark wherever it hit, on an extremely hot fire; and this tempts me once more to illustrate how simply the ordinary steamer of to-day can throw a stiff $1\frac{1}{4}$-inch stream, even though 1,000 feet away from the fire, and to again refer you to Fig. 24.

By this simple arrangement of the double line of common hose the wasted effort — the friction loss — is so lessened that, although it is 1,000 feet from steamer to nozzle, the $1\frac{1}{4}$-inch stream is thrown with the same ease as though the steamer were only 287 feet from the nozzle.

This involves no new principle in hydraulics, and I reiterate it only because I saw it so wofully absent from Lynn a fortnight ago.

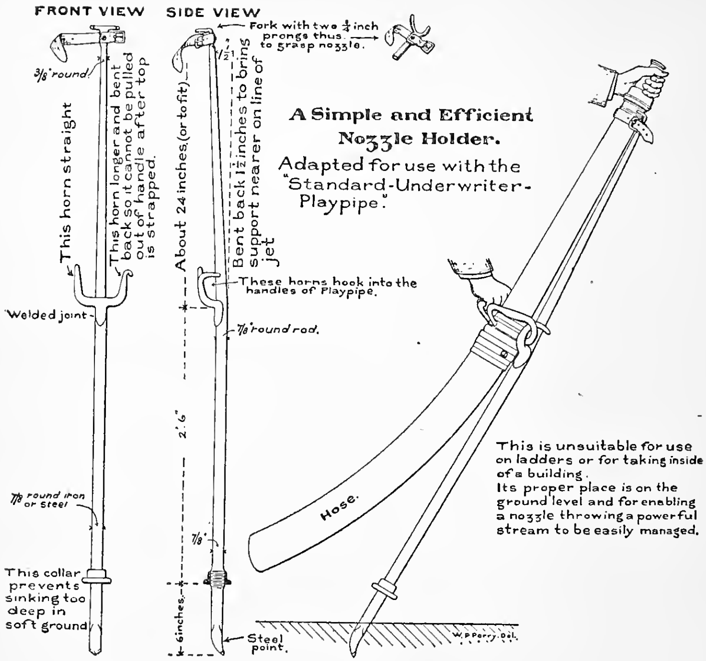


Fig. 25.

A Nozzle-Rest.

Several water-works superintendents have expressed an interest in this handy device, and therefore a cut, from which any intelligent blacksmith can make one, is reproduced here. I devised it a year or two ago for use in factory yards in occasionally testing fire-pumps up to a high pressure when short-handed.

Those of you who manage water-works in cities or towns where the hydrant-pressure is from 100 to 140 pounds per square inch, as is the case at several places in New England, need not be told how difficult it is to hold the hose nozzle under the pressure which this gives, and probably each has seen men tipped over by the recoil when trying alone to hold such powerful streams; and if you will have your blacksmith make one of these, you will be surprised at the ease with which it enables the most powerful stream to be managed.

A pressure of *40 pounds at the nozzle* on a 1⅛-inch stream is about all even a skilled hoseman can conveniently manage, without other men to help him. And a nozzle-pressure of 60 pounds with a 1¼-inch stream will tax the energies of three strong men to hold it fast.

The cheap and simple device illustrated in Fig. 25 will enable a single boy to hold and easily direct a 1¼-inch stream under 100-pound nozzle-pressure (which, if hose were 200 feet long, corresponds to 211 pounds water-pressure at the steamer).

The philosophy of the action of this device is very simple. A nozzle or play-pipe always pulls back with a force just equal to force propelling the jet. Action and reaction are equal. Ordinarily the grasp of the pipe-men and the friction on the ground of the hose near the nozzle have to balance this reaction.

This nozzle-rest, however, furnishes a prop *directly on line* with the force or reaction, and balances all this recoil. So all the hand has to do, except when moving to a new position, is merely to guide its direction.

Please not misunderstand me; this is not a universal attachment to be used at all times, for nine-tenths of the work of a fire department any device of this sort would be only in the way, and useless; but whenever it is desired to project a very powerful stream under high pressure, or whenever, as in certain tests, it is desirable to get along with few men, then it may be extremely valuable to have one of these handy.

One topic more and I am done. You are often called upon by mill managers to run your pipes into their mill-yard and your professional judgment invoked to fix up their hydrant system (I wish it were invoked even more frequently). Whenever that mill is liable to come to the "Factory Mutuals" for insurance, I beg you, gentlemen, to bear the following points in mind:—

1st. *Don't lay any 4-inch pipe for hydrant mains* (unless it be a short piece to a single hydrant or to an unimportant part of the yard); 6-inch pipe is none too big for even the branch pipes, and for a factory worth half a million dollars 8 inch is best for the main circuit around the yard. For a big factory a 12-inch pipe into the yard is by no means extravagant. The carrying capacity of water-pipes may deteriorate greatly with age.

2d. *In planting hydrants, plant them so the whole available number of streams can be concentrated on any particular building of importance without using any line of hose more than 250 feet long.*

3d. Remind the mill managers of a fact which they seldom realize (I don't dare admonish you, who have such long experience in the craft, to keep it in mind yourselves in planting hydrants and pipes about town)—*you can furnish stock and labor and lay 100 feet of the best 6-inch iron pipe for just about the same amount of money that it costs your city to buy 100 feet of first-class 2½-inch fire-hose.* The pipe will carry more water than three lines of the fire-hose, and may last for fifty years, while the fire-hose will have to be renewed in five to eight years. *That cast-iron pipes and hydrants are cheaper than hose, is a maxim that all who are laying out fire protection may well remember.*

4th. *Don't run main pipes under buildings* if it can possibly be avoided, and when it must be done, protect and cover them with earth so that the falling of the building may not break them just when most needed.

5th. For large branches into a building *always put a stop-gate outside the building*, and a safe distance from its walls, by which this may be kept from bleeding the hydrant system if a floor of the building falls.

The Best Kind of Fire-Hose for Factories.

I have been asked by several to name the kind of fire-hose preferred for the protection of mills. The needs are somewhat different from those of city fire departments.

We consider that **for attachment to stand-pipes in stair-towers, or for dry well-ventilated places inside the mill, a thoroughly good unlined linen hose is the best,** and for small hose inside the rooms *good* unlined linen is the best.

It is the best by reason of its superior lightness, compactness, and convenience for quick use by but a single man, and because there is little or no chance of its becoming stuck together by the ordinary heat of the rooms; moreover, such in-

side hose need never be used except in case of actual fire; and linen hose, if kept dry, will retain its good quality unimpaired for many years.

It must be remembered, however, that three pieces out of four of the linen hose ordinarily found in the market are made for insuranee inspectors to look at, rather than for aetual use.

For outside use, or for connection to yard hydrants, rubber-lined cotton hose is very much the best kind.

1st. Because it will not beeome eut and injured by ehafing when lying over sharp corners or sharp gravel nearly so easily as linen does, when subject to the slight vibration due pulsations of fire-pump.

2d. There is very much less loss of pressure by friction in well-made rubber-lined hose than in linen (see page 108), and this makes a serious difference in jet where length is more than 200 feet.

3d. **Rubber-lined hose is best for use in the fortnightly or monthly pump trials**; for whereas linen hose is injured more or less eaeh time it is wet, the durability of rubber-lined hose is improved, if anything, by oeeasionally running a stream of water through it, providing it is well dried afterward.

For inside hose in dye-works, print-works, or factories where air is very damp, rubber-lined cotton hose will generally prove more durable and satisfactory than linen hose.

Linen possesses the property of absorbing moisture from the air to a greater extent than is generally appreciated.

TABLES FOR PRACTICAL USE.

Table A.

This is, in one sense, the most eomplete in its details of the three sets of tables presented, and extends from page 136 to page 155.

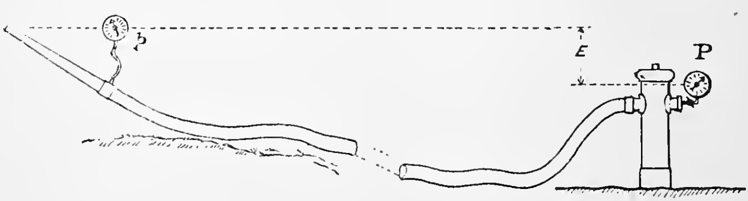
For regular use in pump inspections, Table A is not so convenient as Table B, pages 158 to 163.

For showing the relative difference in pressure lost, aecording to the diameter or length of the hose used, Table C, page 166, unless ehanged, is most convenient.

To understand Table A, turn to page 142, or A No. 4. This gives the data for the 1⅛-inch smooth nozzle. The pressure at the base of the play-pipe is the controlling element. This is what throws the water, and thus governs the height of jet, the quantity, and the friction loss.

We see that a "good" average fire stream requires 40 pounds indicated pressure at base of play-pipe.

By indicated pressure, we mean the pressure which a gauge connected to a play-pipe, as shown at p in the subjoined sketeh, would indicate.



In practice it is seldom convenient to measure the pressure at this point. The pressure is more readily measured at the other end of the hose, at the hydrant or steamer, as shown at P.

Nevertheless, although we do not apply our gauge at the base of the play-pipe, the pressure is there just the same, and is a proper basis for computations.

Turning again to the Table A, No. 4, page 142, and following across the page, we see that for this 40-pound 1⅛-inch stream, —

The extreme drops, with no wind, will rise to a height of . . .	84 feet.
It will be a good practical fire-stream up to a height of . . .	65 "
If elevated at the best angle (about 32°) it will throw the extreme drops, when there is no wind, to a horizontal distance of . .	142 "
At the same time, keeping the effect of a moderate wind in view, we cannot class it as a good, effective fire-stream for a greater horizontal distance of more than	59 "
(In this the stream is not supposed to be horizontal, but is supposed to be elevated at the ordinary working angle of about 30°, and thus this point 59 feet distant would be up in air high as third-story windows.) The number of gallons per minute discharged will be .	238

Height and Distance Reached by Jets.

Tables heretofore published have given **as the height of a jet** corresponding to a given pressure **the extreme height to which the highest drops of water would rise in still air**, and pumps have often been sold with representations based on such misleading data as to the height they would throw. Such data is almost worthless in considering fire protection, for the obvious reasons: first, that the water cannot be thrown in a direct vertical upon a building in flames; second, that, even if it could, the few scattering drops which would reach this height would be of no avail whatever in extinguishing the fire; third, that air still enough to permit these extreme drops to attain this height is not found more than one day in ten, and almost never during a fire. Few persons have any idea how much influence the wind has upon the height that a jet of water can attain. **Merely a moderate summer afternoon breeze will cut down height of extreme drops 10 or 15 per cent.**

Much attention was given to determine for the different pressures the extreme height at which stream was solid and forcible enough to constitute a **good fire-stream.** It was hard to define this exactly within say 5 feet, and say just exactly where the stream ceased to be "good;" but I tried it under many different circumstances, and present the results as based on my best judgment. Some men would undoubtedly set the limit at 10 per cent. higher, but the effect of a moderate wind was taken into account in determining the figures in the table.

Under favorable conditions, with still air, the stream will be in shape to do good execution at a considerably greater distance.

In defining the limit of height as a good effective fire-stream for a given pressure, I have classed as *good* a stream which, at limit named, would enter through a window and barely strike ceiling with force to spatter wall, and which

at limit named had not lost continuity of stream by dividing into a shower of spray, and which at this limit appeared to shoot $\frac{9}{10}$ of the whole body of water inside a 15-inch circle, and $\frac{3}{4}$ of it within a 10-inch circle, as nearly as could be judged by the eye. In setting upon this limit of height **as a good effective stream, the stream was not vertical, but was inclined upward at 75 degrees,** which may be taken as the highest practical working angle.

With regard to the distance reached by jets, the same general remarks just given will also apply. The distance attained by the extreme drops measured as at a firemen's muster is misleading as practical information for fire protection; but that is the way the values in the ordinary tables are derived. A very faint breeze will increase or decrease the distance reached by the extreme drops by 10 per cent.

In fixing the limit of horizontal distance as a **good effective fire-stream, the stream itself is not supposed horizontal,** but it is supposed to be inclined upward at the ordinary working angle of 30 or 45 degrees.

Continuing to follow across the page to past the middle, we see that if our line of $2\frac{1}{2}$-inch hose is 300 feet long, and including an allowance for the ordinary serpentine course in which it runs, — we see that to maintain this good fire-pressure of 40 pounds at the nozzle will require a pressure at the hydrant or at the steamer of —

If the hose be unlined linen	131 pounds.
" " rubber lined, and with inner surface rough . .	120 "
" " " " and with inner surface extremely smooth	81 "

If we follow across the page to a line of hose whose length is 800 feet (and this is a length often called into actual use) we see that to give a good first-class $1\frac{1}{8}$-inch stream at the nozzle requires, if the rubber-lined hose be very rough on the inside, 247 pounds pressure at the steamer. While with the hose of the very smoothest quality, 145 pounds pressure at the steamer will give just the same force to the jet.

Most hose in use in fire departments will come somewhere between these two grades of "inside rough" and "inside smooth," neither of which are exaggerations, but both grades can be found in the market to-day. By reference to the photographs on Fig. 7, page 111, may be seen the exact degree of roughness to which the figures in the following tables apply.

The hose friction varies greatly in different kinds of hose, according to smoothness of inside surface or waterway. As already stated on page 111, salesmen of inferior grades of hose often state with great positiveness (and equal disregard of fact and reason) that "roughness of surface makes no practical difference in flow," that the water lies dead in the little hollows between the ridges, and merely furnishes a cushion on which the main stream slides along," etc. Such notions were conclusively upset by the experiments of the eminent French Engineer Darcy, over thirty years ago; and again proved untrue by the experiments mentioned above. The fact is, that **a rough surface apparently sets the whole stream all the way to its very centre into a**

condition of turmoil and eddying, and all these eddies absorb power. The same is true of iron pipes containing tubercles. An old tubercle-coated 6-inch pipe, in which there is a clear open waterway 5 inches diameter inside of projecting tubercles, may discharge no more water under a given pressure than would a smooth, clean pipe about 4 inches in diameter.

In purchasing new hose, departments are advised to insist on a sample being furnished along with the proposal, and to insist that for acceptance the smoothness must in all cases equal that of sample.

Hydraulic Elements on which Table is Based.

Coefficient of discharge, smooth nozzles	.974
" " ring "	.740
Diameter of hose-couplings	2.50 inches.
Actual diameter of ordinary good $2\frac{1}{2}$-inch rubber-lined hose .	$2\frac{5}{8}$ "
" " " " " " unlined linen hose .	$2\frac{5}{8}$ "
" " " inferior " rubber-lined hose .	2.50 "

Hose supposed to be laid in a curved or crooked line, as in ordinary practice.

Friction loss per 100 feet, with 240 gallons per minute flowing, assumed to be as follows, including effect of curvature and stretch: —

For very best and smoothest rubber-lined hose	13 lbs.
For inferior rubber lined hose with rough interior	26 lbs
For ordinary linen hose	30 lbs.

These were average values, resulting from the experiments already described.

In the original paper algebraic formulæ were presented, adapted to the solution of various problems, but it has not been thought best to reproduce them here.

¾-INCH SMOOTH

This Table may also be

Hydrant Pressure Required—Discharge

	INDICATED PRESSURE by Gauge attached at Base of Play-Pipe, and set level with End of Nozzle	Effective or Static Pressure at Base of Play Pipe.	Extreme Height of Jet.		Extreme Horizontal Distance reached by Jet.		Gallons per Minute Discharged.	Pounds Pressure Required at Hydrant (or first column, through								
								Length 50 ft.			Length 100 ft.			Length 200 ft.		
			Averago of Highest Drops, Vertical Jet, Still Air.	Maximum Limit of Height as Good Effective Fire Stream with Moderate Wind. (Maximum limit as a "fair fire stream" is about 10 per cent. higher.)	Average Extreme Drops at level of Nozzle, with Still Air.	Maximum Limit of Distance as Good Effective Fire Stream with Moderate Wind. (Maximum limit as a "fair fire stream" is about 12 per cent. farther.)		Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.
	lbs.	lbs.	ft.	ft.	ft.	ft.		lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Feeble Streams.	5.	5.0	10	....	18	...	37	5	5	5	6	6	5	6	6	6
	10.	10.1	20	17	36	19	52	11	11	10	12	11	11	13	13	11
	15.	15.1	30	25	54	24	64	16	16	16	17	17	16	19	19	17
	20.	20.2	40	33	72	29	73	22	22	21	23	23	22	26	25	23
	25.	25.2	50	41	86	33	82	27	27	26	29	28	27	32	31	28
Ordinary Fire Pressures.	30.	30.2	59	48	96	37	90	33	32	31	35	34	32	39	38	34
	35.	35.3	69	55	105	41	97	38	38	37	40	40	38	45	44	40
	40.	40.3	78	60	112	44	104	43	43	42	46	46	43	52	50	46
	45.	45.4	86	64	119	47	110	49	48	47	52	51	48	58	57	51
	50.	50.4	93	67	125	50	116	54	54	52	58	57	54	65	63	57
	55.	55.5	99	70	131	52	122	60	59	58	64	63	59	71	69	63
	60.	60.5	104	72	136	54	127	65	65	63	69	68	65	78	76	68
Unusually High Pressures.	65.	65.5	109	74	141	56	132	71	70	68	75	74	70	84	82	74
	70.	70.6	114	76	145	58	137	76	75	73	81	80	75	91	88	80
	75.	75.6	119	78	149	60	142	81	81	79	87	85	81	97	94	85
	80.	80.7	123	79	153	62	147	87	86	84	93	91	86	104	101	91
	85.	85.7	126	80	157	64	151	92	92	89	98	97	92	110	107	97
	90.	90.7	129	81	161	65	156	98	97	94	104	102	97	117	113	102
	95.	95.8	132	82	164	66	160	103	102	99	110	108	102	123	120	108
	100.	100.8	134	83	167	68	164	109	108	105	116	114	108	130	126	114

80 pounds per square inch is now considered best hydrant pressure for general use; 100 lbs. per sq. in. should not be exceeded, except occasionally for very high buildings, or lengths of Hose exceeding 300 feet.

If nozzle is much higher or lower than hydrant, allowance for difference of level must be made on hydrant pressure (10 feet in height corresponds to 4.33 lbs. water pressure).

NOZZLE. (This size of Nozzle gives too small a body of water for extinguishing a fire of much size.)

TABLE A.—No. 1 (From experiments of J. R. FREEMAN, 1888.)

used for ⅞-inch Ring Nozzle.

—Height and Distance of Jet.

Steamer) while stream is flowing, to maintain pressure at base of play-pipe, as per various lengths and kinds of 2½-inch Hose, as below.

Length 300 ft.			Length 400 ft.			Length 500 ft.			Length 600 ft.			Length 800 ft.			L'gth. 1000 ft.		
Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose —Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.
lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
7	7	6	8	8	6	9	8	7	9	9	7	11	10	8	12	11	8
14	14	12	16	15	13	17	16	13	19	17	14	21	20	15	24	22	16
22	21	18	24	23	19	26	24	20	28	26	21	32	30	23	36	34	24
29	28	24	32	30	25	34	32	26	37	35	28	43	40	30	48	45	32
36	35	30	39	38	31	43	41	33	46	44	35	53	50	38	61	56	41
43	41	36	47	45	38	52	49	40	56	52	41	64	60	45	73	67	49
50	48	42	55	53	44	60	57	46	65	61	48	75	70	53	85	78	57
58	55	48	63	60	50	69	65	53	74	70	55	86	80	60	97	89	65
65	62	54	71	68	57	77	73	59	84	79	62	96	90	68	109	101	73
72	69	60	79	75	63	86	81	66	93	87	69	107	100	75	121	112	81
79	76	66	87	83	69	95	89	73	102	96	76	118	110	83	133	123	89
86	83	72	95	90	76	103	97	79	112	105	83	128	119	90	145	134	97
93	90	78	103	98	82	112	106	86	121	114	90	139	129	98	157	145	106
101	97	84	110	105	88	120	114	92	130	122	97	150	139	105	169	156	114
108	104	90	118	113	94	129	122	99	139	131	104	160	149	113	182	168	122
115	111	96	126	120	101	138	130	106	149	140	111	171	159	120	194	179	130
122	117	102	134	128	107	146	138	112	158	148	117	182	169	128	206	190	138
129	124	108	142	135	113	155	146	119	167	157	124	193	179	135	218	201	146
137	131	114	150	143	120	163	154	125	177	166	131	203	189	143	230	212	154
144	138	120	158	150	126	172	163	132	186	175	138	214	199	150	242	223	163

TAKE NOTICE. — The above is pressure at hydrant head ***while stream is flowing.*** The corresponding Static Reservoir Pressure, or Fire-pump Pressure, must be greater than hydrant pressure by an amount equal to friction loss between hydrant-head and pump or reservoir.

⅞-INCH SMOOTH

This Table may also be

Hydrant Pressure Required—Discharge

	INDICATED PRESSURE by Gauge attached at Base of Play-Pipe, and set level with End of Nozzle	Effective or Static Pressure at Base of Play-Pipe.	Extreme Height of Jet. Average of Highest Drops, Vertical Jet, Still Air.	Extreme Height of Jet. Maximum Limit of Height as Good Effective Fire Stream with Moderate Wind.	Extreme Horizontal Distance reached by Jet. Average Extreme Drops at level of Nozzle, with Still Air.	Extreme Horizontal Distance reached by Jet. Maximum Limit of Distance as Good Effective Fire Stream with Moderate Wind.	Gallons per Minute Discharged.	Pounds Pressure Required at Hydrant (or first column, through Length 50 ft. Unlined Linen Hose.	Length 50 ft. Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Length 50 ft. Ordinary best quality Rubber-lined Hose.—Inside Smooth	Length 100 ft. Unlined Linen Hose.	Length 100 ft. Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Length 100 ft. Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Length 200 ft. Unlined Linen Hose.	Length 200 ft. Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Length 200 ft. Ordinary best quality Rubber-lined Hose.—Inside Smooth.
	lbs.	lbs.	ft.	ft.	ft.	ft.		lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Feeble Streams.	5	5.1	11	....	18	...	50	6	6	5	6	6	6	8	7	6
	10.	10.2	21	18	37	21	71	12	11	11	13	13	11	16	15	13
	15.	15.2	31	26	56	27	87	17	17	16	19	19	17	23	22	19
	20.	20.3	41	34	74	33	100	23	23	22	26	25	23	31	30	25
	25.	25.4	51	42	90	38	112	29	29	27	32	31	29	39	37	31
Ordinary Fire Pressures.	30.	30.5	61	49	103	42	123	35	34	33	39	38	34	47	45	38
	35.	35.5	71	56	114	46	133	41	40	38	45	44	40	54	52	44
	40.	40.6	81	62	124	49	142	46	46	43	52	50	46	62	59	50
	45.	45.7	89	67	132	52	150	52	51	49	58	57	51	70	67	57
	50.	50.8	97	71	140	55	159	58	57	54	65	63	57	78	74	63
	55.	55.8	105	74	147	58	166	64	63	60	71	69	63	85	82	69
	60.	60.9	112	77	153	61	174	70	69	65	78	75	69	93	89	75
Unusually High Pressures.	65.	66.0	118	79	158	64	181	75	74	71	84	82	74	101	96	82
	70.	71.0	123	81	163	66	188	81	80	76	90	88	80	109	104	88
	75.	76.1	128	83	168	68	194	87	86	82	97	94	86	117	111	94
	80.	81.2	132	85	172	70	201	93	91	87	103	101	91	124	119	101
	85.	86.3	136	87	176	72	207	99	97	92	110	107	97	132	126	107
	90.	91.3	139	88	180	74	213	104	103	98	116	113	103	140	134	113
	95.	96.4	142	89	183	75	219	110	109	103	123	119	109	148	141	119
	100.	101.5	144	90	186	76	224	116	114	109	129	126	114	155	148	126

Maximum limit as a "fair fire stream" is about 10 per cent. higher.

Maximum limit as a "fair fire stream" is about 12 per cent. further.

80 pounds per square inch is now considered best hydrant pressure for general use; 100 lbs. per sq. in. should not be exceeded, except occasionally for very high buildings, or lengths of Hose exceeding 300 feet.

If nozzle is much higher or lower than hydrant, allowance for difference of level must be made on hydrant pressure (10 feet in height corresponds to 4.33 lbs. water pressure).

NOZZLE.

used for 1-inch Ring Nozzle.

—Height and Distance of Jet.

TABLE A.– No. 2.
(From experiments of J. R. FREEMAN, 1888.)

Steamer) while stream is flowing, to maintain pressure at base of play-pipe, as per various lengths and kinds of 2½-inch Hose, as below.

Length 300 ft.			Length 400 ft.			Length 500 ft.			Length 600 ft.			Length 800 ft.			L'g'h. 1000 ft.		
Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.
lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
9	9	7	10	10	7	12	11	8	13	12	9	16	14	10	18	17	11
18	17	14	21	19	15	23	22	16	26	24	17	31	28	19	37	33	22
27	26	21	31	29	22	35	33	24	39	36	26	47	43	29	55	50	33
36	34	27	42	39	30	47	43	32	52	48	34	63	57	39	73	66	43
45	43	34	52	48	37	59	54	40	65	60	43	78	71	48	91	83	54
54	51	41	62	58	45	70	65	48	78	72	51	94	85	58	110	99	65
64	60	48	73	68	52	82	76	56	91	84	60	109	100	68	128	116	76
73	68	55	83	78	59	94	87	64	104	96	68	125	114	78	146	132	87
82	77	62	94	87	67	105	97	72	117	108	77	141	128	87	164	149	97
91	86	69	104	97	74	117	108	80	130	120	86	156	142	97	183	165	108
100	94	75	114	107	82	129	119	88	143	132	94	172	157	107	201	182	119
109	103	82	125	116	89	140	130	96	156	144	103	188	171	116	219	198	130
118	111	89	135	126	96	152	141	104	169	156	111	203	185	126	237	215	141
127	120	96	145	136	104	164	152	112	182	167	120	219	199	136	255	231	152
136	128	103	156	145	111	175	162	120	195	179	128	234	213	145	....	248	162
145	137	110	166	155	119	187	173	128	208	191	137	250	228	155	....	264	173
154	145	116	177	165	126	199	184	136	221	203	145	....	242	165	...	...	184
163	154	123	187	174	134	211	195	144	234	215	154	....	256	174	....	...	195
173	163	130	197	184	141	222	206	152	247	227	163	....	....	184	....	....	206
182	171	137	208	194	148	234	216	160	260	239	171	....	....	194	....	....	216

TAKE NOTICE. — The above is pressure at hydrant head *while stream is flowing.* The corresponding Static Reservoir Pressure, or Fire-pump Pressure, must be greater than hydrant pressure by an amount equal to friction loss between hydrant-head and pump or reservoir.

1-INCH SMOOTH

Hydrant Pressure Required—Discharge

Class of Stream	INDICATED PRESSURE by Gauge attached at Base of Play-Pipe, and set level with End of Nozzle.	Effective or Static Pressure at Base of Play-Pipe.	Extreme Height of Jet. Average of Highest Drops, Vertical Jet, Still Air.	Extreme Height of Jet. Maximum Limit of Height as Good Effective Fire Stream with Moderate Wind.	Extreme Horizontal Distance reached by Jet. Average Extreme Drops at level of Nozzle, with Still Air.	Extreme Horizontal Distance reached by Jet. Maximum Limit of Distance as Good Effective Fire Stream with Moderate Wind.	Gallons per Minute Discharged.	Pounds Pressure Required at Hydrant (or first column, through — Length 50 ft. Unlined Linen Hose.	Length 50 ft. Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Length 50 ft. Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Length 100 ft. Unlined Linen Hose.	Length 100 ft. Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Length 100 ft. Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Length 200 ft. Unlined Linen Hose.	Length 200 ft. Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Length 200 ft. Ordinary best quality Rubber-lined Hose.—Inside Smooth.
	lbs.	lbs.	ft.	ft.	ft.	ft.		lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Feeble Streams.	5.	5.1	10	....	17	...	66	6	6	6	8	7	6	10	9	7
Feeble Streams.	10.	10.3	21	18	38	21	93	13	12	12	15	14	12	20	18	14
Feeble Streams.	15.	15.4	32	26	58	30	114	19	19	17	23	22	19	29	27	22
Feeble Streams.	20.	20.5	43	35	77	37	132	26	25	23	30	29	25	39	37	29
Ordinary Fire Streams. Fair.	25.	25.6	53	43	94	42	147	32	31	29	38	36	31	49	46	36
Ordinary Fire Streams. Fair.	30.	30.8	63	51	109	47	161	38	37	34	45	43	37	59	55	43
Ordinary Fire Streams. Good.	35.	35.9	73	58	122	51	174	45	44	40	53	51	44	68	64	51
Ordinary Fire Streams. Good.	40.	41.0	83	64	133	55	186	51	50	46	60	58	50	78	73	58
Ordinary Fire Streams. Good.	45.	46.2	92	69	143	58	198	57	56	52	68	65	56	88	83	65
Ordinary Fire Streams. Excellent.	50.	51.3	101	73	152	61	208	64	62	57	75	72	62	98	92	72
Ordinary Fire Streams. Excellent.	55.	56.4	109	76	160	64	218	70	69	63	83	79	69	108	101	79
Ordinary Fire Streams. Excellent.	60.	61.5	117	79	167	67	228	77	75	69	90	87	75	117	110	87
Unusually Strong Streams. (Difficult to hold Nozzle without special appliances.)	65.	66.7	124	82	173	70	237	83	81	75	98	94	81	127	119	94
Unusually Strong Streams.	70.	71.8	130	85	179	72	246	89	87	80	105	101	87	137	128	101
Unusually Strong Streams.	75.	76.9	135	87	184	74	255	96	94	86	113	108	94	147	138	108
Unusually Strong Streams.	80.	82.1	140	89	189	76	263	102	100	92	120	115	100	156	147	115
Unusually Strong Streams.	85.	87.2	144	91	193	78	274	109	106	98	128	123	106	166	156	123
Unusually Strong Streams.	90.	92.3	147	92	197	80	279	115	112	103	135	130	112	176	165	130
Unusually Strong Streams.	95.	97.4	150	94	201	82	287	121	118	109	143	137	118	186	174	137
Unusually Strong Streams.	100.	102.6	152	96	205	83	295	128	125	115	150	144	125	195	183	144

Maximum limit as a "fair fire stream" is about 10 per cent. higher. (Height of jet.)

Maximum limit as a "fair fire stream" is about 12 per cent. farther. (Horizontal distance.)

80 pounds per square inch is now considered best hydrant pressure for general use; 100 lbs. per sq. in. should not be exceeded, except occasionally for very high buildings, or lengths of Hose exceeding 300 feet.

If nozzle is much higher or lower than hydrant, allowance for difference of level must be made on hydrant pressure (10 feet in height corresponds to 4.33 lbs. water pressure).

NOZZLE.

—Height and Distance of Jet.

TABLE A.—No. 3.
(From experiments of J. R. FREEMAN, 1888.)

Steamer) while stream is flowing, to maintain pressure at base of play-pipe, as per various lengths and kinds of 2½-inch Hose, as below.

Length 300 ft.			Length 400 ft.			Length 500 ft.			Length 600 ft.			Length 800 ft.			L'gth. 1000 ft.		
Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.
lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
12	11	8	14	13	9	17	15	10	19	17	11	23	21	13	28	25	15
24	22	16	29	26	18	33	30	20	38	34	22	47	42	26	56	50	30
36	33	25	43	39	28	50	45	30	57	51	33	70	63	39	84	75	45
48	45	33	57	52	37	66	60	41	75	68	45	93	84	52	111	99	60
60	56	41	71	65	46	83	75	51	94	85	56	117	105	65	139	124	75
72	67	49	86	79	55	99	90	61	113	102	67	140	125	79	167	149	90
84	78	57	100	92	64	116	105	71	132	119	78	163	146	92	195	174	105
96	89	66	114	105	73	132	120	81	151	136	89	187	167	105	223	199	120
108	100	74	129	118	83	149	135	91	169	153	100	210	188	118	251	223	135
120	111	82	143	131	92	166	151	102	188	170	111	233	209	131	....	248	151
132	122	90	157	144	101	182	166	112	207	187	122	....	230	144	....	....	166
144	134	98	171	157	110	199	181	122	226	204	134	....	251	157	....	....	181
156	145	107	186	170	119	215	196	132	244	221	145	....	....	170	....	....	196
168	156	115	200	183	128	232	211	142	....	238	156	....	....	183	....	....	211
181	167	123	214	196	138	248	226	152	....	255	167	....	....	196	....	....	226
193	178	131	229	209	147	....	241	162	..	....	178	....	....	209	....	....	241
205	189	139	243	222	156	....	256	173	....	....	189	....	....	222	....	....	....
217	200	147	257	236	165	....	....	183	....	....	200	....	....	236	....	....	....
229	211	156	....	249	174	....	....	193	....	....	211	....	....	249	....	....	....
241	223	164	....	....	183	....	....	203	....	....	223	....	....	....	....	....	....

TAKE NOTICE. — The above is pressure at hydrant head *while stream is flowing.* The corresponding Static Reservoir Pressure, or Fire-pump Pressure, must be greater than hydrant pressure by an amount equal to friction loss between hydrant-head and pump or reservoir.

1⅛-INCH SMOOTH

Hydrant Pressure Required—Discharge

	INDICATED PRESSURE by Gauge attached at Base of Play-Pipe, and set level with End of Nozzle.	Effective or Static Pressure at Base of Play-Pipe.	Extreme Height of Jet. Average of Highest Drops, Vertical Jet, Still Air	Extreme Height of Jet. Maximum Limit of Height as Good Effective Fire Stream with Moderate Wind. (Maximum limit as a "fair fire stream" is about 10 per cent. higher.)	Extreme Horizontal Distance reached by Jet. Average Extreme Drops at level of Nozzle, with Still Air.	Extreme Horizontal Distance reached by Jet. Maximum Limit of Distance as Good Effective Fire Stream with Moderate Wind. (Maximum limit as a "fair fire stream" is about 12 per cent. farther.)	Gallons per Minute Discharged.	Pounds Pressure Required at Hydrant (or first column, through Length 50 ft. Unlined Linen Hose.	Length 50 ft. Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Length 50 ft. Ordinary best quality Rubber-lined Hose.—Inside Smooth	Length 100 ft. Unlined Linen Hose.	Length 100 ft. Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Length 100 ft. Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Length 200 ft. Unlined Linen Hose.	Length 200 ft. Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Length 200 ft. Ordinary best quality Rubber-lined Hose.—Inside Smooth.
	lbs.	lbs.	ft.	ft.	ft.	ft.		lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Feeble Streams.	5.	5.2	11	....	19	...	84	7	7	6	9	9	7	13	12	9
Feeble Streams.	10.	10.4	22	18	39	22	119	15	14	12	18	17	14	26	24	17
Feeble Streams.	15.	15.6	32	27	59	31	146	22	21	19	27	26	21	38	35	26
Feeble Streams.	20.	20.8	43	36	80	38	168	29	28	25	36	34	28	51	47	34
Ordinary Fire Streams. Fair.	25.	26.0	54	44	99	44	188	36	35	31	45	43	35	64	59	43
Ordinary Fire Streams. Fair.	30.	31.2	64	52	115	50	206	44	42	37	55	52	42	77	71	52
Ordinary Fire Streams. Good.	35.	36.4	74	59	130	54	222	51	49	43	64	60	49	89	82	60
Ordinary Fire Streams. Good.	40.	41.7	84	65	142	59	238	58	56	50	73	69	56	102	94	69
Ordinary Fire Streams. Good.	45.	46.9	94	70	152	63	252	65	63	56	82	77	63	115	106	77
Ordinary Fire Streams. Excellent.	50.	52.1	104	75	162	66	266	72	70	62	91	86	70	128	118	86
Ordinary Fire Streams. Excellent.	55.	57.3	113	80	170	69	279	80	77	68	100	95	77	140	130	95
Ordinary Fire Streams. Excellent.	60.	62.5	122	83	178	72	291	87	84	74	109	103	84	153	141	103
Unusually Strong Streams. (Difficult to hold Nozzle without special appliances.)	65.	67.7	130	86	185	75	303	94	91	81	118	112	91	166	153	112
Unusually Strong Streams.	70.	72.9	136	88	191	77	314	101	98	87	127	120	98	179	165	120
Unusually Strong Streams.	75.	78.1	142	90	197	79	325	109	105	93	136	129	105	191	177	129
Unusually Strong Streams.	80.	83.3	146	92	203	81	336	116	112	99	145	138	112	204	188	138
Unusually Strong Streams.	85.	88.5	150	94	209	83	346	123	119	106	154	146	119	217	200	146
Unusually Strong Streams.	90.	93.7	153	96	214	85	356	130	126	112	164	155	126	230	212	155
Unusually Strong Streams.	95.	98.9	156	98	219	87	366	138	133	118	173	163	133	242	224	163
Unusually Strong Streams.	100.	104.1	158	99	224	89	376	145	140	124	182	172	140	255	236	172

80 pounds per square inch is now considered best hydrant pressure for general use; 100 lbs. per sq. in. should not be exceeded, except occasionally for very high buildings, or lengths of Hose exceeding 300 feet.

If nozzle is much higher or lower than hydrant, allowance for difference of level must be made on hydrant pressure (10 feet in height corresponds to 4.33 lbs. water pressure).

NOZZLE. (This is the size preferred for general outside use.) —Height and Distance of Jet.

TABLE A.—No. 4. (From experiments of J. R. FREEMAN, 1888.)

Steamer) while stream is flowing, to maintain pressure at base of play-pipe, as per various lengths and kinds of $2\frac{1}{2}$-inch Hose, as below.

Length 300 ft.			Length 400 ft.			Length 500 ft.			Length 600 ft.			Length 800 ft.			L'gth. 1000 ft.		
Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.
lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
16	15	10	20	18	12	24	21	13	28	25	15	35	31	18	42	37	21
33	30	20	40	36	24	48	43	27	55	49	30	70	62	36	84	75	43
49	45	31	60	54	35	71	64	40	82	74	45	105	93	54	127	112	64
66	60	41	80	73	47	95	85	54	110	98	60	139	123	73	168	149	85
82	75	51	101	91	59	119	107	67	137	123	75	174	154	91	211	186	107
99	90	61	121	109	71	143	128	80	165	147	90	209	185	109	253	223	128
115	105	71	141	127	82	166	149	94	192	172	105	243	216	127	....	261	149
131	120	81	161	145	94	190	171	107	220	196	120	278	247	145	....	....	171
148	135	92	181	163	106	214	192	120	247	221	135	....	278	163	....	....	192
164	150	102	201	181	118	238	213	134	274	245	150	....	....	181	....	....	213
181	165	112	221	200	130	262	235	147	....	270	165	....	....	200	....	....	235
197	180	122	241	218	141	....	256	160	....	....	180	....	....	218	....	....	256
214	195	132	261	236	153	....	....	174	....	....	195	....	....	236	....	....	....
230	209	143	....	254	165	....	....	187	....	....	209	....	....	254	....	....	....
246	224	153	....	....	177	....	....	201	....	....	224	....	....	....	....	....	....
263	239	163	....	....	188	....	....	214	....	....	239	....	....	....	....	....	....
....	254	173	....	....	200	....	....	227	....	....	254	....	....	....	....	....	....
....	....	183	....	....	212	....	....	241	....	....	....	....	....	....	....	....	....
....	....	194	....	....	224	....	....	254	....	....	....	....	....	....	....	....	....
....	....	204	....	....	236	....	....	....	....	....	....	....	....	....	....	....	....

TAKE NOTICE. — The above is pressure at hydrant head ***while stream is flowing.*** The corresponding Static Reservoir Pressure, or Fire-pump Pressure, must be greater than hydrant pressure by an amount equal to friction loss between hydrant-head and pump or reservoir.

1¼-INCH SMOOTH

Hydrant Pressure Required—Discharge

	INDICATED PRESSURE by Gauge attached at Base of Play-Pipe, and set level with End of Nozzle.	Effective or Static Pressure at Base of Play-Pipe.	Extreme leight of Jet. Vertical Jet, Still Air.	Extreme leight of Jet. Maximum Limit of Height as Good Effective Fire Stream with Moderate Wind.	Extreme Horizontal Distance reached by Jet. Average Extreme Drops at level of Nozzle, with Still Air.	Extreme Horizontal Distance reached by Jet. Maximum Limit of Distance as Good Effective Fire Stream with Moderate Wind.	Gallons per Minute Discharged.	Pounds Pressure Required at Hydrant (o[r] first column, through Length 50 ft. Unlined Linen Hose.	Length 50 ft. Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Length 50 ft. Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Length 100 ft. Unlined Linen Hose.	Length 100 ft. Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Length 100 ft. Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Length 200 ft. Unlined Linen Hose.	Length 200 ft. Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Length 200 ft. Ordinary best quality Rubber-lined Hose.—Inside Smooth.
	lbs.	lbs.	t.	ft.	ft.	ft.		lbs.	lbs	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Feeble Streams.	5.	5.3	11	....	19	...	105	8	8	7	11	11	8	17	15	11
	10.	10.6	22	19	40	22	148	17	16	14	23	21	16	34	31	21
	15.	15.9	33	28	62	32	181	25	24	21	34	32	24	51	47	32
	20.	21.2	44	37	83	40	209	34	32	27	45	42	32	68	62	42
Ordinary Fire Streams. Fair.	25.	26.5	55	46	103	47	234	42	40	34	57	53	40	85	77	53
	30.	31.8	66	53	119	54	256	51	49	41	68	63	49	102	93	63
Good.	35.	37.1	76	60	134	59	277	59	57	48	79	74	57	119	109	74
	40.	42.4	86	67	148	63	296	68	65	55	91	84	65	136	124	84
	45.	47.8	97	72	159	67	314	76	73	62	102	95	73	153	140	95
Excellent.	50.	53.1	07	77	169	70	331	85	81	68	113	106	81	170	155	106
	55.	58.4	17	81	178	73	347	93	89	75	124	116	89	187	170	116
	60.	63.7	26	85	186	76	363	102	97	82	136	127	97	204	186	127
Unusually Strong Streams. (Difficult to hold Nozzle without special appliances.)	65.	69.0	33	88	193	79	377	110	105	89	147	137	105	221	201	137
	70.	74.3	40	91	200	81	392	118	113	96	158	148	113	238	217	148
	75.	79.6	45	93	207	83	405	127	121	103	170	158	121	255	232	158
	80.	84.9	50	95	213	85	419	135	129	110	181	169	129	....	248	169
	85.	90.2	54	97	219	88	432	144	137	116	192	179	137	....	263	179
	90.	95.5	57	99	225	90	444	152	145	123	204	190	145	....	....	190
	95.	100.8	59	100	231	92	456	161	154	130	215	201	154	....	....	201
	100.	106.1	61	101	236	93	468	169	162	137	226	211	162	....	....	211

Maximum limit as a "fair fire stream" is about 10 per cent. higher.

Maximum limit as a "fair fire stream" is about 12 per cent. farther.

80 pounds per square inch is now considered best hydrant pressure for general use; 100 lbs. per sq. in. should not be exceeded, except occasionally for very high buildings, or lengths of Hose exceeding 300 feet.

If nozzle is much higher or lower than hydrant, allowance for difference of level must be made on hydrant pressure (10 feet in height corresponds to 4.33 lbs. water pressure).

NOZZLE. (This size is well adapted for serious fires where water supply is ample and line of hose not too long.) —Height and Distance of Jet.

TABLE A.—No. 5 (From experiments of J. R. FREEMAN, 1888.)

Steamer) while stream is flowing, to maintain pressure at base of play-pipe, as per various lengths and kinds of 2½-inch Hose, as below.

Length 300 ft.			Length 400 ft.			Length 500 ft.			Length 600 ft.			Length 800 ft.			L'gth. 1000 ft.		
Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.
lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
23	20	13	28	25	15	34	30	18	40	35	20	51	45	25	63	55	30
46	41	26	57	51	31	68	61	36	80	71	41	103	90	51	125	110	61
68	61	39	85	76	47	102	91	54	120	106	61	154	136	76	188	165	91
91	82	52	114	102	62	137	121	72	159	141	82	205	181	101	251	220	121
114	102	65	142	127	77	171	152	90	199	176	102	256	226	127	....	275	152
136	123	78	171	152	93	205	182	108	239	212	123	....	271	152	....	....	182
159	143	91	199	178	109	239	212	126	279	247	142	....	....	178	....	...	212
182	164	104	227	203	124	273	243	144	....	283	164	....	....	203	....	....	243
205	184	117	256	229	140	....	273	162	....	....	184	....	....	229	....	....	....
227	204	130	....	254	155	....	....	180	....	....	204	....	....	254	....	....	....
249	225	143	....	..	170	....	....	198	....	....	225	..	....	....	....	....	....
....	245	156	....	....	186	....	....	216	....	....	245	....	....	..	....	....	....
....	266	169	....	....	201	....	....	234	....	....	....	....	....	....	....	....	....
....	....	182	....	....	217	....	....	252	....	....	....	....	....	....	....	....	....
....	....	195	....	....	232	....	....	....	....	....	....	....	....	....	....	....	....
....	....	208	....	....	248	....	....	....	....	....	....	....	....	....	....	....	....
....	....	221	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
....	....	234	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
....	....	247	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
....	....	261	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....

TAKE NOTICE. — The above is pressure at hydrant head *while stream is flowing.* The corresponding Static Reservoir Pressure, or Fire-pump Pressure, must be greater than hydrant pressure by an amount equal to friction loss between hydrant-head and pump or reservoir.

1⅜-INCH SMOOTH

Hydrant Pressure Required—Discharge

	INDICATED PRESSURE by Gauge attached at Base of Play-Pipe, and set level with End of Nozzle.	Effective or Static Pressure at Base of Play Pipe.	Extreme Height of Jet. Average of Highest Drops, Vertical Jet, Still Air.	Extreme Height of Jet. Maximum Limit of Height as Good Effective Fire Stream with Moderate Wind.	Extreme Horizontal Distance reached by Jet. Average Extreme Drops at level of Nozzle, with Still Air.	Extreme Horizontal Distance reached by Jet. Maximum Limit of Distance as Good Effective Fire Stream with Moderate Wind.	Gallons per Minute Discharged.	Pounds Pressure Required at Hydrant (or first column, through Length 50 ft. Unlined Linen Hose.	Length 50 ft. Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Length 50 ft. Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Length 100 ft. Unlined Linen Hose.	Length 100 ft. Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Length 100 ft. Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Length 200 ft. Unlined Linen Hose.	Length 200 ft. Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Length 200 ft. Ordinary best quality Rubber-lined Hose.—Inside Smooth.
	lbs.	lbs.	ft.	ft.	ft.	ft.		lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Feeble Streams.	5	5.5	12	....	19	...	128	10	10	8	15	13	10	23	21	13
	10.	10.9	23	20	41	23	182	20	19	16	29	27	19	46	42	27
	15.	16.4	34	29	63	33	222	31	29	23	44	40	29	69	62	40
	20.	21.8	45	38	85	42	257	41	39	31	58	53	39	92	83	53
Ordinary Fire Streams. Fair.	25.	27.3	56	47	106	49	287	51	48	39	73	67	48	115	104	67
	30.	32.7	67	55	123	56	315	61	58	47	87	80	58	139	125	80
Good.	35.	38.2	78	62	138	62	340	71	67	54	102	94	67	162	146	94
	40.	43.7	89	69	152	66	363	82	77	62	116	107	77	185	166	107
	45.	49.1	100	74	164	70	385	92	87	70	131	120	87	208	187	120
Excellent.	50.	54.6	111	79	175	73	406	102	96	78	145	134	96	231	208	134
	55.	60.0	121	83	184	76	426	112	106	86	160	147	106	254	229	147
	60.	65.5	131	87	192	79	445	122	116	93	174	160	116	....	250	160
Unusually Strong Streams. (Difficult to hold Nozzle without special appliances.)	65.	70.9	138	90	200	82	463	133	125	101	189	174	125	....	....	174
	70.	76.4	144	92	207	84	480	143	135	109	203	187	135	....	....	187
	75.	81.9	149	95	214	86	497	153	145	117	218	200	145	....	....	200
	80.	87.3	154	97	220	88	514	163	154	124	232	214	154	....	....	214
	85.	92.8	158	99	226	90	529	174	164	132	247	227	164	....	....	227
	90.	98.2	161	100	232	92	545	184	173	140	261	240	173	....	....	240
	95.	103.7	163	101	238	94	560	194	183	148	....	254	183	....	....	254
	100.	100.1	165	103	243	96	574	204	193	156	....	....	193	....	....	....

Maximum limit as a "fair fire stream" is about 10 per cent. higher.

Maximum limit as a "fair fire stream" is about 12 per cent. farther.

80 pounds per square inch is now considered best hydrant pressure for general use; 100 lbs. per sq. in. should not be exceeded, except occasionally for very high buildings, or lengths of Hose exceeding 300 feet.

If nozzle is much higher or lower than hydrant, allowance for difference of level must be made on hydrant pressure (10 feet in height corresponds to 4.33 lbs. water pressure).

1⅜ s.

NOZZLE.

—Height and Distance of Jet.

TABLE A.—No. 6.
(From experiments of J. R. FREEMAN, 1888.)

Steamer) while stream is flowing, to maintain pressure at base of play-pipe, as per various lengths and kinds of $2\frac{1}{2}$-inch Hose, as below.

Length 300 ft.			Length 400 ft.			Length 500 ft.			Length 600 ft.			Length 800 ft.			L'gth. 1000 ft.		
Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.
lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
32	28	17	40	36	21	49	43	25	57	51	28	74	66	36	92	80	43
63	56	34	81	71	42	98	86	49	115	101	56	149	131	71	184	161	86
95	85	51	121	107	62	147	129	74	172	152	85	224	196	107	275	241	129
127	113	68	161	143	83	195	173	98	230	202	113	299	262	143	....	321	173
158	141	85	201	178	104	244	216	123	287	253	141	....	....	178	....	....	216
190	169	103	242	214	125	293	259	147	....	....	169	....	....	2[illegible]4	....	....	259
222	198	120	282	250	146	....	....	172	....	....	198	....	....	250	....	....	....
253	226	137	....	....	166	....	....	196	....	....	226	....	....	....	....	....	....
....	254	154	....	....	187	....	....	221	....	....	254	....	....	....	....	....	....
....	....	171	....	....	208	....	....	245	....	....	....	....	....	....	....	....	....
....	....	188	....	....	229	....	....	270	....	....	....	....	....	....	....	....	....
....	....	205	....	....	250	....	....	....	....	....	....	....	....	....	....	....	....
....	....	222	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
....	....	239	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
....	....	256	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
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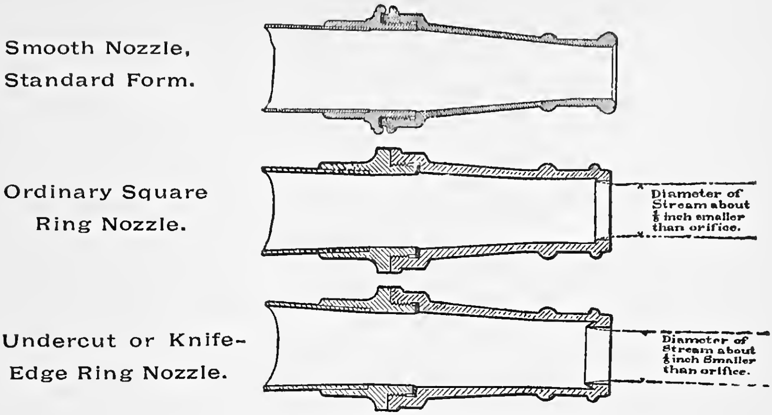
TAKE NOTICE. — The above is pressure at hydrant head *while stream is flowing.* The corresponding Static Reservoir Pressure, or Fire-pump Pressure, must be greater than hydrant pressure by an amount equal to friction loss between hydrant-head and pump or reservoir.

$1\frac{3}{8}$ s.



RING NOZZLES.

We find so many ring nozzles in use that it was thought best to prepare tables giving their discharge. The advocates of this style of nozzle stand up for its alleged merits stoutly, and therefore, as already stated, I tried some experiments intended to settle the question. Ring nozzles were prepared of such size as to discharge just the same number of gallons per minute as certain smooth nozzles, and the two, ring and smooth, then tested side by side. One set of these experiments is illustrated in the cut opposite. Another series of experiments was tried at another place, with jets more nearly horizontal. Both series of experiments were made with the greatest care, and at times when there was almost absolutely no wind; and were afterward repeated in the presence of the corps of inspectors. **These experiments all showed conclusively that the ring nozzle does not possess the slightest advantage over the smooth nozzle.** The smooth nozzle proved slightly superior: its stream was more solid, and reached a little farther; this difference was very small, however.

Other experiments proved that **a ring nozzle discharges only three-quarters as much water per minute as a smooth nozzle of the same size.** The sharp corner of the ring contracts the stream, and if any one will measure diameter of stream close to nozzle with a pair of common machinist's calipers, he will find it about ⅛ inch smaller than the hole from which it issues.

The only use of the ring nozzle is to make a show of playing a larger stream than is the fact. The apparent advantage of the ring nozzle, which has misled many firemen, is easily explained. **The result is the same as if a smaller nozzle were used,** while hydrant-pressure remained the same. The number of gallons per minute flowing being less, the pressure lost by friction through hose is less; therefore pressure at base of play-pipe remains greater, therefore stream goes higher.

For ⅞-inch and 1-inch ring nozzles the discharge is almost exactly the same as for smooth nozzles ⅛ inch smaller; therefore no special tables for these two sizes of ring nozzles are given. **For 7-8-inch Ring Nozzle use table for 3-4-inch Smooth Nozzle, and for 1-inch Ring Nozzle use table for 7-8-inch Smooth Nozzle.**

(Discharge of 1-in. Ring is same as 7/8-in. Smooth.)
(Discharge of 7/8-in. Ring is same as 3/4-in. Smooth.)

1 1/8-INCH RING

Hydrant Pressure Required—Discharge

Class of Stream	INDICATED PRESSURE by Gauge attached at Base of Play-Pipe, and set level with End of Nozzle.	Effective or Static Pressure at Base of Play-Pipe.	Extreme Height of Jet: Average of Highest Drops, Vertical Jet, Still Air.	Extreme Height of Jet: Maximum Limit of Height as Good Effective Fire Stream with Moderate Wind.	Extreme Horizontal Distance reached by Jet: Average Extreme Drops at level of Nozzle, with Still Air.	Extreme Horizontal Distance reached by Jet: Maximum Limit of Distance as Good Effective Fire Stream with Moderate Wind.	Gallons per Minute Discharged.	Pounds Pressure Required at Hydrant (or first column, through Length 50 ft.: Unlined Linen Hose.	Length 50 ft.: Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Length 50 ft.: Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Length 100 ft.: Unlined Linen Hose.	Length 100 ft.: Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Length 100 ft.: Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Length 200 ft.: Unlined Linen Hose.	Length 200 ft.: Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Length 200 ft.: Ordinary best quality Rubber-lined Hose.—Inside Smooth.
	lbs.	lbs.	ft.	ft.	ft.	ft.		lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Feeble Streams.	5.	5.1	10	....	17	...	63	6	6	6	7	7	6	9	9	7
	10.	10.2	21	17	37	20	89	13	12	11	15	14	12	19	18	14
	15.	15.4	32	26	57	29	110	19	18	17	22	21	18	28	27	21
	20.	20.5	42	34	76	36	126	25	25	23	29	28	25	38	35	28
Ordinary Fire Streams. Fair.	25.	25.6	52	42	93	41	141	31	31	28	37	35	31	47	44	35
	30.	30.7	62	49	107	45	155	38	37	34	44	42	37	56	53	42
Good.	35.	35.8	72	56	120	49	167	44	43	40	51	49	43	66	62	49
	40	40.9	82	62	131	53	179	50	49	45	59	56	49	75	71	56
	45.	46.0	91	67	141	56	190	56	55	51	66	63	55	85	80	63
Excellent.	50.	51.2	99	70	150	59	200	63	61	57	73	70	61	94	88	70
	55.	56.3	107	73	158	62	210	69	67	63	80	77	67	103	97	77
	60.	61.4	115	76	164	65	219	75	74	68	88	84	74	113	106	84
Unusually Strong Streams. (Difficult to hold Nozzle without special appliances.)	65.	66.5	122	79	170	67	228	82	80	74	95	91	80	122	115	91
	70.	71.6	128	82	176	69	237	88	86	80	102	98	86	132	124	98
	75.	76.7	133	84	181	71	245	94	92	85	110	106	92	141	133	106
	80.	81.8	138	86	186	73	253	100	98	91	117	113	98	150	141	113
	85.	87.0	142	88	190	75	261	107	104	97	124	120	104	160	150	120
	90.	92.1	145	89	194	77	268	113	110	102	132	127	110	169	159	127
	95.	97.2	148	91	198	79	276	119	117	108	139	134	117	179	168	134
	100.	102.3	150	93	202	80	283	125	123	114	146	141	123	188	177	141

Maximum limit as a "fair fire stream" is about 10 per cent. higher.

Maximum limit as a "fair fire stream" is about 12 per cent. farther.

NOTE.—The above figures for Ring Nozzle Discharges will apply to any ordinary form of Ring accurately enough for practical purposes, but apply especially to ordinary form of Ring Nozzle with square shoulder $\frac{1}{16}$ or $\frac{1}{8}$ inch deep.

Ring Nozzles with "undercut" or "knife-edge" shoulder, discharge, as ordinarily constructed, about three per cent. less than quantity given above.

NOZZLE.

—Height and Distance of Jet.

TABLE A.—No. 7. (From experiments of J. R. FREEMAN, 1888.)

Steamer) while stream is flowing, to maintain pressure at base of play-pipe, as per various lengths and kinds of $2\frac{1}{2}$-inch Hose, as below.

Length 300 ft.			Length 400 ft.			Length 500 ft.			Length 600 ft.			Length 800 ft.			L'gth. 1000 ft.		
Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.
lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
12	11	8	14	12	9	16	14	10	18	16	11	22	20	12	26	23	14
23	21	16	27	25	18	31	29	19	35	32	21	44	39	25	52	47	29
34	32	24	41	37	27	47	43	29	53	48	32	66	59	37	78	70	43
46	43	32	54	50	35	63	57	39	71	64	43	88	79	50	104	93	57
57	53	40	68	62	44	78	71	49	89	80	53	110	98	62	130	116	71
69	64	48	81	75	53	94	86	58	106	96	64	131	118	75	156	140	86
80	75	56	95	87	62	110	100	68	124	112	75	153	138	87	182	163	100
92	85	64	108	100	71	125	114	78	142	128	85	175	157	100	208	186	114
103	96	71	122	112	80	141	128	88	160	145	96	197	177	112	234	209	128
115	106	79	136	125	88	156	143	97	177	161	106	219	197	125	260	233	143
126	117	87	149	137	97	172	157	107	195	177	117	241	216	137	....	256	157
138	128	95	163	149	106	188	171	117	213	193	128	263	236	149	....	....	171
149	138	103	176	162	115	203	185	127	230	209	138	....	256	162	....	....	185
161	149	111	190	174	124	219	200	136	248	225	149	....	....	174	....	....	200
172	160	119	203	187	132	235	214	146	266	241	160	....	....	187	....	....	214
184	170	127	217	199	141	250	228	156	....	257	170	....	....	199	....	....	228
195	181	135	231	212	150	....	242	166	....	....	181	....	....	212	....	....	242
207	192	143	244	224	159	....	257	175	....	....	192	....	....	224	....	....	257
218	202	151	258	237	168	....	....	185	....	....	202	....	....	237	....	....	....
230	213	159	....	249	177	....	....	195	....	....	213	....	....	249	....	....	....

TAKE NOTICE.—The above is pressure at hydrant head *while stream is flowing.* The corresponding Static Reservoir Pressure, or Fire-pump Pressure, must be greater than hydrant pressure by an amount equal to friction loss between hydrant-head and pump or reservoir.

$1\frac{1}{8}$ r.

1¼-INCH RING

Hydrant Pressure Required — Discharge

INDICATED PRESSURE by Gauge attached at Base of Play-Pipe, and set level with End of Nozzle.		Effective or Static Pressure at Base of Play-Pipe.	Extreme Height of Jet. Average of Highest Drops, Vertical Jet, Still Air.	Extreme Height of Jet. Maximum Limit of Height as Good Effective Fire Stream with Moderate Wind. (Maximum limit as a "fair fire stream" is about 10 per cent. higher.)	Extreme Horizontal Distance reached by Jet. Average Extreme Drops at level of Nozzle, with Still Air.	Extreme Horizontal Distance reached by Jet. Maximum Limit of Distance as Good Effective Fire Stream with Moderate Wind. (Maximum limit as a "fair fire stream" is about 12 per cent. farther.)	Gallons per Minute Discharged.	Pounds Pressure Required at Hydrant (or first column, through Length 50 ft. Unlined Linen Hose.	Length 50 ft. Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Length 50 ft. Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Length 100 ft. Unlined Linen Hose.	Length 100 ft. Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Length 100 ft. Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Length 200 ft. Unlined Linen Hose.	Length 200 ft. Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Length 200 ft. Ordinary best quality Rubber-lined Hose.—Inside Smooth.
	lbs.	lbs.	ft.	ft.	ft.	ft.		lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Feeble Streams.	5.	5.2	11	....	20	...	79	7	7	6	9	8	7	12	11	8
Feeble Streams.	10.	10.4	21	17	39	21	111	14	13	12	17	16	13	24	22	16
Feeble Streams.	15.	15.5	32	26	58	30	136	21	20	18	26	24	20	35	33	24
Feeble Streams.	20.	20.7	43	35	78	37	157	28	27	24	34	33	27	47	44	33
Ordinary Fire Streams. Fair.	25.	25.9	53	43	97	42	176	35	34	30	43	41	34	59	55	41
Ordinary Fire Streams. Fair.	30.	31.1	63	49	112	48	192	42	40	36	51	49	40	71	66	49
Ordinary Fire Streams. Good.	35.	36.2	73	56	126	51	208	49	47	42	60	57	47	82	76	57
Ordinary Fire Streams. Good.	40.	41.4	83	63	138	55	222	56	54	48	69	65	54	94	87	65
Ordinary Fire Streams. Good.	45.	46.6	93	68	149	59	236	63	61	54	77	73	61	106	98	73
Ordinary Fire Streams. Excellent.	50.	51.8	102	72	157	62	248	70	67	61	86	81	67	118	109	81
Ordinary Fire Streams. Excellent.	55.	57.0	111	76	164	65	260	77	74	67	94	90	74	130	120	90
Ordinary Fire Streams. Excellent.	60.	62.1	119	79	172	68	272	84	81	73	103	98	81	141	131	98
Unusually Strong Streams. (Difficult to hold Nozzle without special appliances.)	65.	67.3	127	81	178	71	283	90	88	79	111	106	88	153	142	106
Unusually Strong Streams.	70.	72.5	133	84	185	73	294	97	94	85	120	114	94	165	153	114
Unusually Strong Streams.	75.	77.7	138	86	191	75	304	104	101	91	129	122	101	177	164	122
Unusually Strong Streams.	80.	82.8	143	88	196	77	314	111	108	97	137	130	108	188	175	130
Unusually Strong Streams.	85.	88.0	147	90	201	79	324	118	115	103	146	138	115	200	186	138
Unusually Strong Streams.	90.	93.2	149	92	206	81	333	125	121	109	154	147	121	212	197	147
Unusually Strong Streams.	95.	98.4	152	94	211	82	342	132	128	115	163	155	128	224	208	155
Unusually Strong Streams.	100.	103.5	154	95	215	84	351	139	135	121	171	163	135	236	218	163

NOTE.— The above figures for Ring Nozzle Discharges will apply to any ordinary form of Ring accurately enough for practical purposes, but apply especially to ordinary form of Ring Nozzle with square shoulder $\frac{1}{16}$ or $\frac{1}{8}$ inch deep.

Ring Nozzles with "undercut" or "knife-edge" shoulder, discharge, as ordinarily constructed, about three per cent. less than quantity given above.

NOZZLE.
—Height and Distance of Jet.

TABLE A.—No. 8.
(From experiments of J. R. FREEMAN, 1888.)

Steamer) while stream is flowing, to maintain pressure at base of play-pipe, as per various lengths and kinds of $2\frac{1}{2}$-inch Hose, as below.

Length 300 ft.			Length 400 ft.			Length 500 ft.			Length 600 ft.			Length 800 ft.			L'gth. 1000 ft.		
Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.
lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
15	14	10	18	17	11	21	19	12	25	22	14	31	28	17	38	33	19
30	27	19	36	33	22	43	39	25	49	44	27	62	55	33	75	66	39
45	41	29	55	49	33	64	58	37	74	66	41	93	83	49	112	100	58
60	55	38	73	66	44	86	77	49	99	88	55	124	111	66	150	133	77
75	69	48	91	83	55	107	96	62	123	110	69	155	138	83	187	166	96
90	82	57	109	99	66	128	116	74	148	132	82	186	166	99	225	199	116
105	96	67	127	115	76	150	135	86	172	154	96	217	193	115	262	232	135
120	110	76	146	132	87	171	154	99	197	176	110	248	221	132	....	266	154
135	123	86	164	148	98	193	173	111	222	199	123	279	249	148	....	....	173
150	137	95	182	165	109	214	193	123	246	221	137	....	276	165	....	....	193
165	151	105	200	181	120	236	212	135	271	243	151	....	....	181	....	....	212
180	164	114	218	198	131	257	231	148	....	265	164	....	....	198	....	....	231
195	178	124	237	214	142	....	251	160	....	....	178	....	....	214	....	....	251
210	192	133	255	231	153	....	....	172	....	....	192	....	....	231	....	....	....
225	206	143	....	247	164	....	....	185	....	....	206	....	....	247	....	....	....
240	219	152	....	264	175	....	....	197	....	....	219	....	....	264	....	....	....
255	233	162	....	....	186	....	....	209	....	....	233	....	....	....	....	....	....
....	247	172	....	....	197	....	....	222	....	....	247	....	....	....	....	....	....
....	260	181	....	....	208	....	....	234	....	....	260	....	....	....	....	....	....
....	....	191	....	....	218	....	....	246	....	....	....	....	....	....	....	....	....

TAKE NOTICE. — The above is pressure at hydrant head ***while stream is flowing.*** The corresponding Static Reservoir Pressure, or Fire-pump Pressure, must be greater than hydrant pressure by an amount equal to friction loss between hydrant-head and pump or reservoir.

$1\frac{1}{4}$ r.

1⅜-INCH RING

Hydrant Pressure Required—Discharge

	INDICATED PRESSURE by Gauge attached at Base of Play-Pipe, and set level with End of Nozzle.	Effective or Static Pressure at Base of Play-Pipe.	Extreme Height of Jet. Average of Highest Drops, Vertical Jet, Still Air.	Extreme Height of Jet. Maximum Limit of Height as Good Effective Fire Stream with Moderate Wind.	Extreme Horizontal Distance reached by Jet. Average Extreme Drops at level of Nozzle, with Still Air.	Extreme Horizontal Distance reached by Jet. Maximum Limit of Distance as Good Effective Fire Stream with Moderate Wind.	Gallons per Minute Discharged.	Pounds Pressure Required at Hydrant (or first column, through — Length 50 ft. Unlined Linen Hose.	Length 50 ft. Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Length 50 ft. Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Length 100 ft. Unlined Linen Hose.	Length 100 ft. Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Length 100 ft. Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Length 200 ft. Unlined Linen Hose.	Length 200 ft. Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Length 200 ft. Ordinary best quality Rubber-lined Hose.—Inside Smooth.
	lbs.	lbs.	ft.	ft.	ft.	ft.		lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Feeble Streams.	5.	5.3	11	....	20	..	96	8	8	7	10	10	8	15	14	10
Feeble Streams.	10.	10.5	22	17	39	21	136	16	15	13	21	19	15	30	28	19
Feeble Streams.	15.	15.8	32	27	59	31	166	24	23	20	31	29	23	45	41	29
Feeble Streams.	20.	21.1	43	36	79	38	192	32	30	26	41	39	30	60	55	39
Ordinary Fire Streams. Fair.	25.	26.3	53	44	99	45	214	40	38	33	52	48	38	75	69	48
Ordinary Fire Streams. Fair.	30.	31 6	64	51	116	50	235	48	46	39	62	58	46	91	83	58
Ordinary Fire Streams. Good.	35.	36.8	74	58	131	55	253	55	53	46	72	68	53	106	97	68
Ordinary Fire Streams. Good.	40.	42.1	85	64	144	59	271	63	61	53	82	77	61	121	111	77
Ordinary Fire Streams. Good.	45.	47.4	95	69	154	63	287	71	68	59	93	87	68	136	124	87
Ordinary Fire Streams. Excellent.	50.	52.6	105	74	164	66	303	79	76	66	103	97	76	151	138	97
Ordinary Fire Streams. Excellent.	55.	57.9	114	78	172	69	318	87	84	72	113	106	84	166	152	106
Ordinary Fire Streams. Excellent.	60.	63.2	123	81	180	72	332	95	91	79	124	116	91	181	166	116
Unusually Strong Streams. (Difficult to hold Nozzle without special appliances.)	65.	68.4	131	84	187	75	346	103	99	85	134	126	99	196	180	126
Unusually Strong Streams.	70.	73.7	137	86	194	77	359	111	106	92	144	135	106	211	193	135
Unusually Strong Streams.	75.	79.0	142	88	200	79	371	119	114	98	155	145	114	226	207	145
Unusually Strong Streams.	80.	84.2	147	90	206	81	383	127	122	105	165	155	122	241	221	155
Unusually Strong Streams.	85.	89 5	150	92	212	82	395	135	129	112	175	164	129	257	235	164
Unusually Strong Streams.	90.	94.7	153	94	217	84	407	143	137	118	186	174	137	....	249	174
Unusually Strong Streams.	95.	100.0	156	96	222	86	418	150	144	125	196	184	144	....	263	184
Unusually Strong Streams.	100.	105.3	158	97	227	88	429	158	152	131	206	193	152	....	....	193

Maximum limit as a "fair fire stream" is about 10 per cent. higher.

Maximum limit as a "fair fire stream" is about 12 per cent. farther.

NOTE.— The above figures for Ring Nozzle Discharges will apply to any ordinary form of Ring accurately enough for practical purposes, but apply especially to ordinary form of Ring Nozzle with square shoulder $\frac{1}{16}$ or $\frac{1}{8}$ inch deep.

Ring Nozzles with "undercut" or "knife-edge" shoulder, discharge, as ordinarily constructed, about three per cent. less than quantity given above.

NOZZLE.
—Height and Distance of Jet.

TABLE A.—No. 9.
(From experiments of J. R. FREEMAN, 1888.)

Steamer) while stream is flowing, to maintain pressure at base of play-pipe, as per various lengths and kinds of $2\frac{1}{2}$-inch Hose, as below.

Length 300 ft.			Length 400 ft.			Length 500 ft.			Length 600 ft.			Length 800 ft.			L'gth. 1000 ft.		
Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.
lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
20	18	12	25	22	14	29	26	16	34	30	18	44	39	22	53	47	26
40	36	24	49	44	28	59	53	32	68	61	36	88	77	44	107	94	53
60	54	35	74	66	41	88	79	48	103	91	54	131	116	66	160	141	79
79	72	47	99	88	55	118	105	64	137	122	72	175	155	88	213	188	105
99	90	59	123	111	69	147	131	79	171	152	90	219	193	111	267	235	131
119	108	70	148	133	83	177	157	95	205	182	108	263	232	133	....	282	157
139	126	82	173	155	97	206	184	111	240	213	126	....	271	155	....	...	184
159	144	94	197	177	111	236	210	127	274	243	144	....	....	177	....	....	210
179	162	106	222	199	124	265	236	143	....	274	162	....	....	199	....	....	236
199	180	117	247	221	138	....	263	159	....	....	180	....	....	221	....	....	263
219	198	129	271	243	152	....	....	175	....	....	198	...	....	243	....	....	....
238	216	141	....	265	166	....	....	191	....	....	216	....	....	265	....	....	....
258	234	153	....	....	180	....	....	207	....	....	234	....	....	....	....	....	....
....	251	164	....	....	193	....	....	222	....	....	251	....	....	....	....	....	....
....	....	176	....	....	207	....	....	238	....	....	....	....	....	....	....	....	....
....	....	188	....	....	221	....	....	254	....	....	....	....	....	....	....	....	....
....	....	200	....	....	235	....	....	....	....	....	....	....	....	....	....	....	....
....	....	211	....	....	249	....	....	....	....	....	....	....	....	....	....	....	....
....	....	223	....	....	263	....	....	....	....	....	....	....	....	....	....	....	....
....	....	235	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....

TAKE NOTICE. — The above is pressure at hydrant head ***while stream is flowing.*** The corresponding Static Reservoir Pressure, or Fire-pump Pressure, must be greater than hydrant pressure by an amount equal to friction loss between hydrant-head and pump or reservoir.

$1\frac{3}{8}$ r.

Table B.

Pump Inspection Tables.

These were designed primarily for the use of insurance inspectors or mill superintendents, for testing fire-pumps, to see if they were in good order, and would deliver as many gallons per minute as they were rated to throw.

The $1\frac{1}{8}$-inch smooth nozzle stream, with a pressure of 40 or 45 pounds at nozzle, is the standard fire-stream used as basis for estimating capacities of fire-pumps, and in general a hydrant-pressure of 80 to 100 pounds is considered most desirable.

These tables (B, No. 1, and B, No. 2) are also very convenient for the use of water-works superintendents in measuring the water used for special purposes. It will be seen that the amount discharged varies with the quality of the hose, but by the use of a little judgment in interpolating between the values for very smooth hose and very rough hose, according to the grade used, the tables will give results which are certain within five per cent., and generally closer than this, and close enough for most practical purposes.

The results will be a little more accurate when 50 feet of hose is used than for 100 feet, since the effect of any peculiarity in the hose is proportionately less.

These tables are of use as a convenient means of measuring the number of gallons that a pipe system can supply in a given part of the city without reducing the pressure below a certain limit.

If it is desired to know the discharge of a nozzle on a line of hose longer than 100 feet, Table A may be used, thus: Suppose nozzle is $1\frac{1}{4}$ inch smooth, line of hose medium rough and 500 feet long, hydrant pressure, 150 pounds.

Looking in Table A, No. 5, under column headed "Length 500 feet," and interpolating:

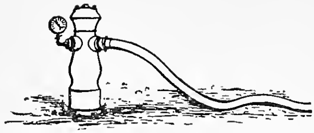
We see that with smoothest hose, gallons per minute = 302.
We see that with rough hose, gallons per minute = 232.

Thus the discharge would be somewhere between these two.

---

[1] These tables are not designed for the exact gauging of discharge of pumping-engines, mentioned on page 103.

To get the very great accuracy mentioned on page 102 requires a special piezometer close to play-pipe and a very careful measurement of diameter of nozzle orifice, and will generally involve a special computation.



PUMP INSPECTION

Discharge of Nozzles attached

HYDRANT PRESSURE indicated while Stream is flowing by Gauge attached to Hydrant, as shown.	1⅜-Inch Smooth Nozzle. Gals. per Min.			1¼-Inch Smooth Nozzle. Gals. per Min.			1⅛-Inch Smooth Nozzle. Gals. per Min.			1-Inch Smooth Nozzle. Gals. per Min.			⅞-Inch Smooth Nozzle, or 1-inch Ring Nozzle. Gals. per Min.		
Lbs. per sq. in.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.
5	90	92	103	80	82	90	70	71	75	59	59	62	47	47	48
10	127	131	146	114	116	127	99	101	107	83	84	87	66	67	68
15	155	160	179	140	143	154	121	123	131	101	102	106	81	81	84
20	180	185	206	161	164	179	140	142	151	117	118	123	93	94	96
25	201	207	230	180	184	200	156	158	169	131	132	137	104	105	107
30	220	226	251	197	202	219	171	173	184	143	144	150	114	115	118
35	238	245	272	213	218	236	184	188	199	154	156	162	123	124	127
40	255	262	291	227	233	253	197	201	213	165	167	173	132	133	136
45	270	278	309	241	247	269	209	213	226	175	177	184	140	141	144
50	284	293	325	255	260	283	221	224	238	184	186	194	147	148	152
55	298	307	341	267	273	296	232	235	250	193	195	204	154	155	159
60	311	320	357	279	285	309	242	245	261	202	204	213	161	162	167
65	324	333	371	290	296	322	252	255	272	210	213	221	168	169	173
70	336	346	385	301	307	334	261	265	281	218	221	230	174	176	180
75	348	358	399	311	318	344	270	275	291	226	228	238	181	182	186
80	359	370	412	322	329	357	279	284	301	233	236	246	186	188	192
85	371	382	425	332	339	369	288	293	310	240	243	253	192	193	198
90	381	393	437	341	349	379	296	301	319	247	250	261	197	199	204
95	392	403	449	350	358	390	304	309	328	253	257	268	203	204	209
100	402	414	461	359	368	400	312	317	337	260	264	275	208	210	215

Quantities are stated in United States gallons of 231 cubic inches.

TABLES.

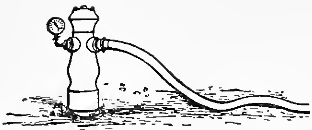
TABLE B.—No. 1.
(From experiments of J. R. FREEMAN, 1888.)

to 50 Feet of 2½-inch Hose.

¾-Inch Smooth Nozzle, or ⅞-inch Ring Nozzle. Gals. per Min.			1⅜-Inch Ring Nozzle. Gals. per Min.			1¼-Inch Ring Nozzle. Gals. per Min.			1⅛-Inch Ring Nozzle. Gals. per Min.			HYDRANT PRESSURE.
Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Lbs. per sq. in.
36	36	37	75	76	84	66	67	70	56	56	59	5
50	50	51	108	110	118	94	96	101	80	81	84	10
61	61	62	132	135	144	115	117	124	98	99	103	15
71	71	72	152	155	167	133	135	143	113	114	119	20
79	80	81	170	174	187	149	151	159	126	128	133	25
86	87	88	187	191	205	163	165	175	138	140	145	30
93	93	95	201	206	221	176	179	189	149	151	157	35
100	100	101	215	219	237	188	191	202	159	162	168	40
106	106	108	229	233	251	200	203	214	169	172	178	45
112	112	113	241	245	264	211	214	226	179	181	188	50
117	117	119	253	257	277	221	224	237	187	189	197	55
122	122	124	264	269	289	231	234	247	196	198	205	60
127	127	129	275	280	301	240	244	257	205	206	214	65
132	132	134	285	291	313	249	253	267	212	213	222	70
137	137	139	295	301	324	258	262	276	219	221	230	75
141	142	144	305	311	334	266	270	285	226	228	237	80
145	146	148	314	320	345	274	279	294	233	235	244	85
149	150	152	323	329	355	282	287	303	239	242	252	90
153	154	156	332	338	364	290	295	311	246	249	259	95
158	159	161	340	347	374	298	303	319	253	255	266	100

NOTE.—The above figures for Ring Nozzle Discharges will apply to any ordinary form of Ring accurately enough for practical purposes, but apply especially to ordinary form of Ring Nozzle with square shoulder $\frac{1}{16}$ or $\frac{1}{8}$ inch deep.

Ring Nozzles with "under-cut" or "knife-edge" shoulder, discharge, as ordinarily constructed, about 3 per cent. less than quantity given above.



PUMP INSPECTION

Discharge of Nozzles attached

HYDRANT PRESSURE indicated while Stream is flowing by Gauge attached to Hydrant, as shown.	$1\frac{3}{8}$-Inch Smooth Nozzle. Gals. per Min.			$1\frac{1}{4}$-Inch Smooth Nozzle. Gals. per Min.			$1\frac{1}{8}$-Inch Smooth Nozzle. Gals. per Min.			1-Inch Smooth Nozzle. Gals. per Min.			$\frac{7}{8}$-Inch Smooth Nozzle, or 1-inch Ring Nozzle. Gals. per Min.		
Lbs. per sq. in.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.
5	75	79	93	70	72	82	62	64	71	54	55	59	44	45	47
10	107	111	131	98	102	116	88	91	100	76	78	83	63	63	66
15	131	136	160	121	125	143	108	111	123	93	95	102	76	77	81
20	151	157	185	139	144	164	125	128	142	107	110	118	88	89	94
25	169	176	207	155	161	184	139	143	158	120	122	132	99	100	105
30	185	192	226	170	176	202	152	156	173	132	134	144	108	110	115
35	200	208	245	184	190	218	165	169	188	142	145	156	117	119	124
40	214	222	262	197	204	233	176	181	201	152	155	167	125	127	133
45	226	236	278	209	216	247	187	192	213	161	165	177	132	134	141
50	239	249	293	220	228	260	197	202	224	170	174	186	139	142	148
55	251	261	307	231	239	273	207	212	235	178	182	195	146	148	155
60	261	273	320	241	250	285	216	222	245	186	190	204	153	155	162
65	272	284	333	251	260	296	225	231	255	194	198	213	159	161	169
70	282	294	346	261	270	307	233	240	265	201	205	221	165	167	176
75	292	304	358	270	279	319	241	248	275	208	212	228	171	173	182
80	301	314	370	278	288	329	249	256	284	215	219	236	177	179	188
85	311	324	382	287	297	339	257	264	293	222	226	243	182	185	193
90	320	333	393	295	306	349	264	272	301	228	233	250	188	190	199
95	329	342	403	303	314	358	272	279	309	234	239	257	192	195	204
100	337	351	414	311	322	368	279	287	317	240	245	264	197	200	210

Quantities are stated in United States gallons of 231 cubic inches.

TABLES.

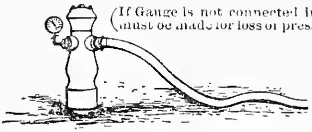
to 100 Feet of 2½-inch Hose.

TABLE B.—No. 2.
(From experiments of J. R. FREEMAN, 1888.)

¾-Inch Smooth Nozzle, or ⅞-inch Ring Nozzle. Gals. per Min.			1⅜-Inch Ring Nozzle. Gals. per Min.			1¼-Inch Ring Nozzle. Gals. per Min.			1⅛-Inch Ring Nozzle. Gals. per Min.			HYDRANT PRESSURE.
Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Lbs. per sq. in.
34	34	35	67	69	78	60	62	68	52	53	57	5
48	49	50	94	97	110	85	87	96	74	75	81	10
59	60	61	115	120	135	104	107	117	90	92	99	15
68	69	71	133	138	155	120	123	135	105	107	114	20
76	77	79	149	154	174	134	138	151	117	119	128	25
84	84	87	163	169	191	147	151	165	128	130	140	30
90	91	93	176	182	206	159	163	179	139	141	151	35
97	97	100	188	195	219	169	174	191	148	151	162	40
103	103	106	200	207	233	180	185	203	157	160	172	45
108	109	112	211	218	245	190	195	214	165	169	181	50
113	114	117	221	229	257	199	204	224	173	177	189	55
118	119	122	231	239	269	208	213	234	181	185	198	60
123	124	127	241	248	280	217	222	244	189	192	206	65
128	129	132	250	258	291	225	230	253	195	199	213	70
132	133	137	259	267	301	233	239	262	203	206	221	75
137	138	142	267	275	311	240	246	270	209	213	228	80
141	142	146	275	284	320	247	254	279	215	219	235	85
145	146	150	283	292	329	255	261	287	222	226	242	90
149	150	154	291	300	338	262	269	295	228	232	249	95
153	154	158	299	308	347	269	275	302	234	238	255	100

NOTE.—The above figures for Ring Nozzle Discharges will apply to any ordinary form of Ring accurately enough for practical purposes, but apply especially to ordinary form of Ring Nozzle with square shoulder $\frac{1}{16}$ or $\frac{1}{8}$ inch deep.

Ring Nozzles with "under-cut" or "knife-edge" shoulder, discharge, as ordinarily constructed, about 3 per cent. less than quantity given above.



(If Gauge is not connected in this manner, proper allowance must be made for loss of pressure between Gauge and Hydrant.)

PUMP INSPECTION

The degree of accuracy attained in estimating of the two preceding tables — B, No. 1 and

HYDRANT PRESSURE	Quantity of Water Discharged per minute through ordinary 2½-inch Fire Hose, (United States Gallons of 231 cubic inches.) Open Hose Butt. No Play-								
indicated while Stream is flowing by Gauge attached to Hydrant, as shown.	Length 25 feet.			Length 50 feet.			Length 100 feet.		
Lbs. per sq. in.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose." Inside Rough.	Ordinary best quality Rubber-lined Hose. Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose." Inside Rough.	Ordinary best quality Rubber-lined Hose. Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose." Inside Rough.	Ordinary best quality Rubber-lined Hose. Inside Smooth.
	If Hydrant were of Style A, discharge would be 5 per cent. greater.	If Hydrant were of Style A, discharge would be 5 per cent. greater.	If Hydrant were of Style A, discharge would be 9 per cent. greater.	If Hydrant were of Style A, discharge would be 3 per cent. greater.	If Hydrant were of Style A, discharge would be 3 per cent. greater.	If Hydrant were of Style A, discharge would be 6 per cent. greater.	If Hydrant were of Style A, discharge would be 1½ per cent. greater.		
10	231	242	297	176	188	242	132	140	188
15	283	297	363	217	230	297	161	171	230
20	326	343	419	251	266	343	186	199	266
25	365	383	468	281	297	383	208	222	297
30	400	420	514	307	326	420	228	243	326
35	432	453	554	332	352	453	246	262	352
40	462	484	593	355	376	484	264	280	376
45	490	514	630	377	399	514	280	297	399
50	516	542	664	398	420	542	294	313	420
55	541	568	696	416	440	568	308	328	440
60	565	594	726	434	460	594	322	343	460
65	588	618	756	452	480	618	336	358	480
70	610	641	784	470	498	641	348	371	498
75	632	663	812	486	515	663	360	384	515
80	652	685	....	502	532	685	372	397	532
85	672	706	....	518	548	706	383	409	548
90	692	727	....	533	564	727	394	421	564
95	712	747	....	547	579	747	405	432	579
100	730	766	....	561	594	766	416	443	594
110	766	806	....	588	623	806	436	465	623
120	800	....	....	614	651	....	456	486	651

NOTE. — The above values are based on experiments with these kinds of Hose attached to a Chapman 4-way Independent Gate Hydrant (Coeff. Disch. by Expt. 0.[illegible]1). So far as influence of kind of Hydrant upon discharge is concerned, the same values are correct enough for practical purposes, except as noted in margin of columns.

It will be noted that this table gives, for each length, the discharge through the best or smoothest hose, and gives, also, discharge for same length of Hose with roughest water-way. By use of a little judgment in interpolating between these two values, error, in ordinary use of table need not exceed 10 per cent.

TABLES.—"Open Butts."

Table B.—No. 3.

discharge through "Open Butt" is, not nearly so great as may be attained by the methods B, No. 2—by reason of greater influence of form of Hydrant and differences in Hose.

with Couplings of 2½-inch Bore. Pipe or Nozzle attached.				Discharge through Open Butt of Hydrant, without Hose attached.	
Length 200 feet.		Length 400 feet.		HYDRANT PRESSURE indicated while Stream is flowing by Gauge attached to Hydrant, as shown.	Discharge of One Nipple of Chapman 4-Way Independent Gate Hydrant. — Diameter of Outlet exactly 2½ inches.
Inferior Rubber-lined Cotton "Mill Hose." Inside Rough.	Ordinary best quality Rubber-lined Hose. Inside Smooth.	Inferior Rubber-lined Cotton "Mill Hose." Inside Rough.	Ordinary best quality Rubber-lined Hose. Inside Smooth.	Lbs. per sq. in.	Gals. per Min.
102	140	74	102	10	419
125	171	90	125	15	513
144	199	104	144	20	592
161	222	116	161	25	663
177	243	127	177	30	725
190	262	137	190	35	783
204	280	146	204	40	837
217	297	155	217	45	888
228	313	164	228	50	936
239	328	172	239	55	982
250	343	179	250	60	1026
260	358	186	260	65	1067
270	371	194	270	70	1108
279	384	201	279	75	1147
288	397	208	288	80	1184
297	409	215	297	85	1221
306	421	221	306	90	1256
314	432	227	314	95	1290
322	443	232	322	100	1326
338	465	243	338	110	....
354	486	254	354	120	....

NOTE.—Slight peculiarities of construction in different makes of Hydrants so affect discharge from open butts of Hydrants without Hose, that these figures apply only approximately to discharge of Hydrants in general.

By using good judgment in applying corrections as per notes below, results accurate to within 10 per cent. may generally be obtained.

(Style A.)—Ordinary Matthews (R. D. Wood & Co.'s) Hydrant without independent gates, inside corner being rounded off, will probably discharge about 20 per cent. more.

(Style B.)—Ordinary Chapman Hydrants without independent gates have square inside corners, and will probably discharge about 10 per cent. more.

For the ordinary Ludlow and Lowry Independent-Gate Hydrants or Chucks, figures in table are probably nearly correct.

If diameter of outlet is not exactly 2½ inches, an additional correction, as follows, must be made:—

Diameter.	Add.	Deduct.
2⅝	10 %	....
$2\frac{9}{16}$	5 %	....
$2\frac{7}{16}$	....	5 %
2⅜	....	10 %
2¼	....	19 %

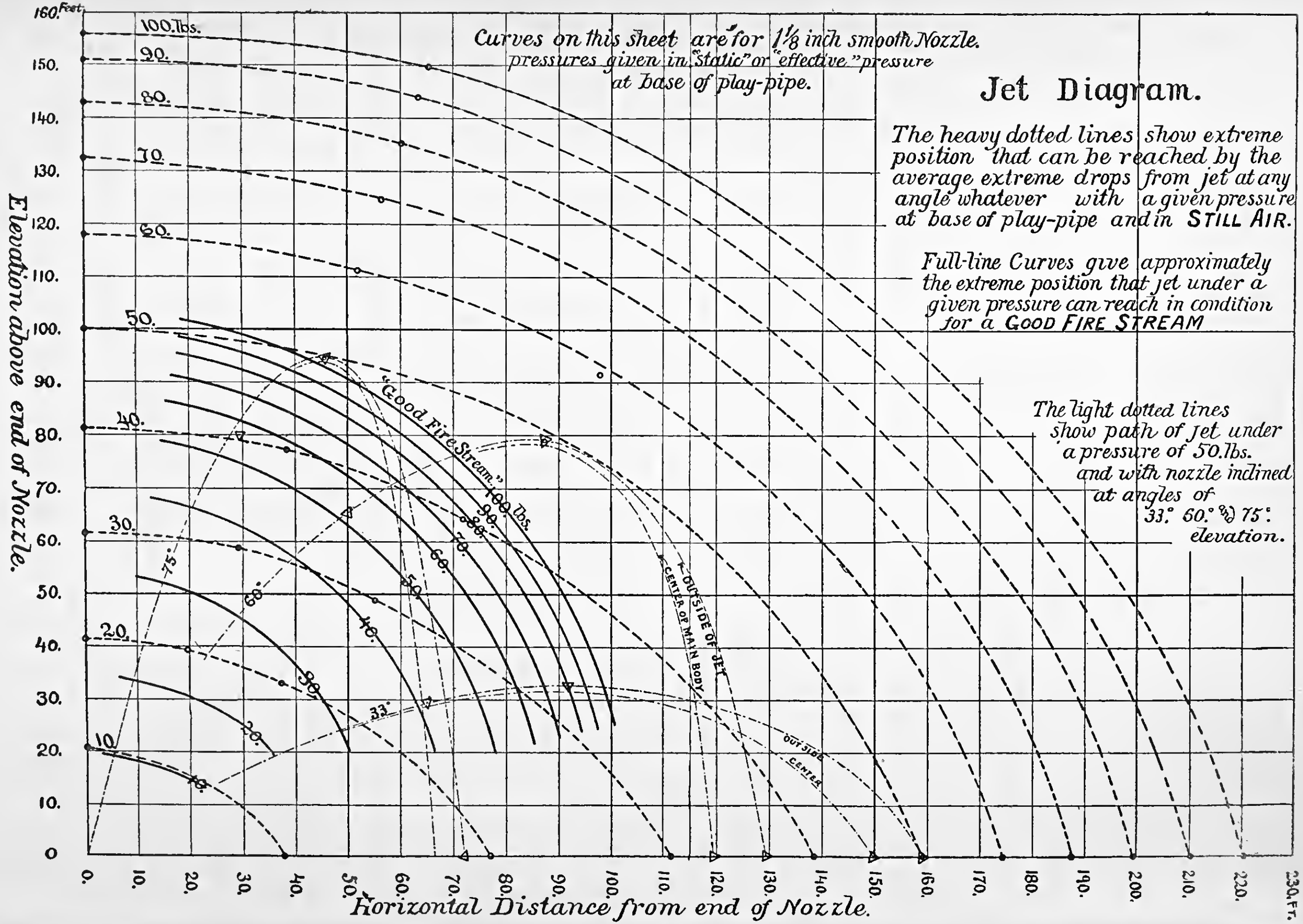

Curves on this sheet are for 1⅛ inch smooth Nozzle.
pressures given in "Static" or "effective" pressure at base of play-pipe.
Jet Diagram.
The heavy dotted lines show extreme position that can be reached by the average extreme drops from jet at any angle whatever with a given pressure at base of play-pipe and in STILL AIR.
Full-line Curves give approximately the extreme position that jet under a given pressure can reach in condition for a GOOD FIRE STREAM
The light dotted lines show path of jet under a pressure of 50.lbs. and with nozzle inclined at angles of 33.° 60.° & 75.° elevation.
"Good Fire Stream."
100 lbs.
OUTSIDE OF JET
CENTER OF MAIN BODY
OUTSIDE
CENTER
Elevation above end of Nozzle.
Horizontal Distance from end of Nozzle.
160. Feet
230. Ft.

Fig. 26.

Jet Diagram. — Fig. 26.

This contains information in very handy form as to the distance a jet can reach in any direction whatever.

It applies particularly to the 1⅛-inch jet, but for nearly all practical purposes will answer for jets of from 1 inch to 1½ inches in diameter.

Table C.

This is of interest mainly in illustrating what can be done with a given hydrant-pressure, according to length and kind of hose used.

Note the difference in effective height and force of jet, dependent on whether 500 feet or even 250 feet of hose is used, or whether 50 feet is used, as in the ordinary practice test.

Note, also, the inferiority of linen hose for use in long lines, such as are called for in connection with yard hydrants.

Thus suppose that at a given mill there is available a static pressure of 80 pounds, and that the hydrant pipes are of such ample size that pressure at hydrant will be 70 pounds when streams are playing.

We see from table that if 1⅛-inch nozzles are used, the height of the effective fire-streams obtainable will be : —

With 50-foot line of 2½-in. linen hose	73 feet.
" 250 " " " " " "	42 "
" 500 " " " " " "	27 "
With 50-foot line of best and smoothest 2½-in. rubber-lined hose .	81 "
" 250 " " " " " " " " " .	61 "
" 500 " " " " " " " " " .	46 "

Note how quickly the inferiority of 2 inch hose develops when length much exceeds 50 or 100 feet.

Thus : with 250 feet of 2½-in. linen, effective height of stream = 56 feet.
" 250 " " 2-in. " " " " " = 20 "

Note also the effect which even ⅛-inch increase in diameter has in reducing friction loss in the hose.

Thus, with 500 feet of smoothest and best rubber-lined hose —

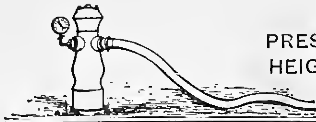
If diam. be exactly 2½ in., effective height of stream will be 39 feet.
If diam. be ⅛th in. larger, " " " " " " 46 "

Three-Inch Hose.

It will be noted that in Table C values are given for fire-hose of 2¾ inches and 3 inches internal diameter. Very little hose of these sizes has yet got into practical use; but the writer has for some months been urging several of the leading hose-makers to introduce such sizes as matters of regular stock, for the reasons stated on page 113, to which reference may be made.

TABLE C.

(From experiments of J. R. FREEMAN, 1888.)



PRESSURE in lbs. per sq. in. indicated at base of play-pipe,
HEIGHT, greatest, as good effective fire stream in moderate wind,
VOLUME in U. S. gallons per minute,

of Jet obtainable with a given Hydrant Pressure, according to Size, Kind, and Length of Hose used.

TAKE NOTICE.—This "Given Hydrant Pressure" is pressure at the Hydrant, measured as shown in sketch, ***while stream is flowing.*** The Fire Pump Pressure (or Static Reservoir Pressure) must, meanwhile, be greater than this Hydrant Pressure by an amount equal to friction-loss between Pump and Hydrant. No general statement of the magnitude of this friction-loss can be made, as it depends on length and size of pipe-system, and number of streams being drawn, and may be anywhere from 5 to 40 or more pounds. In a thoroughly first-class Mill Hydrant System, this friction-loss through main pipes and valves ought not to generally exceed 10 or 15 lbs.

		1-Inch Smooth Nozzle.				1⅛-Inch Smooth Nozzle. This is size now generally preferred for outside use.								1¼-Inch Smooth Nozzle.			
Available Hydrant Pressure while Stream is Flowing⟶		40	60	80	100	40	50	60	70	80	90	100	120	40	60	80	100
50 ft. Ordinary 2-in. Unlined Linen Hose. (Diam. couplings 2-in., but inside diam. hose 2⅛-in.)	Noz. Pressure	24	35	47	59	19	23	28	33	37	42	47	56	15	22	29	36
	Height for Fire	42	58	71	78	34	41	49	56	61	67	72	81	28	41	52	61
	Galls. per Min.	144	174	202	226	164	180	199	216	229	244	258	282	181	219	252	282
50 ft. Ordinary 2½-in. Unlined Linen Hose. (Diam. couplings 2½-in., but inside diam. hose 2⅝-in.)	Noz. Pressure	31	47	63	78	28	35	41	48	55	62	69	83	24	36	47	59
	Height for Fire	52	71	81	88	49	59	66	73	80	84	88	93	44	61	74	84
	Galls. per Min.	164	202	233	261	199	222	241	261	279	296	312	342	230	282	322	359
50 ft. Best 2½-in. Rubber-Lined Cotton Hose. Inside surface very smooth. (Diam. couplings 2½-in., inside diam. hose 2⅝-in.)	Noz. Pressure	35	52	70	87	32	40	48	56	64	73	81	97	29	44	58	73
	Height for Fire	58	74	85	91	55	65	73	81	85	89	92	98	52	71	83	92
	Galls. per Min.	174	212	246	275	212	238	261	282	301	321	338	370	252	307	358	400
250 ft. Ordinary 2-in. Unlined Linen Hose. (Diam. couplings 2-in., but inside diam. hose 2⅛-in.)	Noz. Pressure	9	14	19	23	6	8	9	11	13	14	16	19	4	6	9	11
	Height for Fire	17	24	33	40	13	15	17	20	23	25	29	34	9	13	17	21
	Galls. per Min.	90	110	128	141	102	106	16	126	140	147	150	164	97	120	139	155
250 ft. Ordinary 2½-in. Unlined Linen Hose. (Diam. couplings 2½-in., but inside diam. hose 2⅝-in.)	Noz. Pressure	18	28	37	46	14	17	21	24	27	31	34	41	10	15	20	25
	Height for Fire	32	49	60	70	25	31	38	42	47	54	58	66	19	28	37	46
	Galls. per Min.	126	155	179	200	147	156	172	184	196	209	220	241	148	181	209	234
250 ft. Inferior 2½-in. Rubber-Lined "Mill Hose." Inside surface rough and uneven. (Inside diam. hose and coupling each exactly 2½-in.)	Noz. Pressure	20	30	39	49	15	19	22	26	30	34	37	45	11	17	22	28
	Height for Fire	35	51	63	72	27	34	39	46	52	58	61	70	21	32	41	50
	Galls. per Min.	132	161	184	206	146	164	177	192	206	220	229	252	155	192	219	247
250 ft. Best 2½-in. Rubber-Lined Cotton Hose. Inside surface very smooth. (Diam. couplings 2½-in., inside diam. hose 2⅝-in.)	Noz. Pressure	26	39	52	65	21	27	32	37	43	48	53	64	17	25	34	42
	Height for Fire	45	63	74	82	38	47	55	61	68	73	78	85	32	46	59	69
	Galls. per Min.	150	184	212	237	172	196	212	229	247	261	274	301	192	234	273	304

500 ft. Ordinary 2½-in. Unlined Linen Hose. (Diam. coupling 2½-in., but inside diam. hose 2⅝-in.)	Noz. Pressure	12	18	24	30	8	11	13	15	17	19	21	25	6	9	12	15
	Height for Fire	21	32	42	51	15	20	23	27	31	34	38	44	13	17	23	28
	Galls. per Min.	101	125	144	161	106	126	140	146	156	164	172	188	120	139	162	181
500 ft. Inferior 2½-in. Rubber-Lined "Mill Hose." Inside surface rough and uneven. (Inside diam. hose and coupling each exactly 2½-in.)	Noz. Pressure	13	20	27	33	9	12	14	16	19	21	23	28	7	10	13	17
	Height for Fire	23	35	46	55	17	22	25	29	34	38	41	49	13	19	24	32
	Galls. per Min.	106	132	153	169	116	130	147	150	164	172	180	199	120	148	169	192
500 ft. 2½-in. Rubber-Lined Cotton Hose. Inside surface very smooth. (Inside diam. hose and coupling each exactly 2½-in.)	Noz. Pressure	18	26	35	44	13	16	19	22	26	29	32	38	9	14	19	23
	Height for Fire	32	45	58	68	23	29	34	39	46	50	55	63	17	26	35	42
	Galls. per Min.	125	150	174	196	140	150	164	177	192	202	212	232	139	175	204	225
500 ft. Standard 2½-in. Rubber-Lined Cotton Hose. Inside surface very smooth. (Diam. coupling 2½-in., but inside diam. hose 2⅝-in.)	Noz. Pressure	20	30	39	49	15	19	22	26	30	34	37	45	11	17	22	28
	Height for Fire	35	51	63	72	27	34	39	46	52	58	61	70	21	32	41	50
	Galls. per Min.	132	161	184	206	146	164	177	192	206	220	229	252	155	192	219	247
500 ft. 2¾-in. Rubber-Lined Cotton Hose. Inside surface very smooth. (Coupling 2½-in. bore, with taper. Inside diam. hose 2¾-in.)	Noz. Pressure	22	33	44	55	17	21	26	30	34	38	43	51	13	20	26	32
	Height for Fire	38	55	68	76	31	38	46	52	58	63	68	76	24	37	47	56
	Galls. per Min.	138	169	196	218	156	172	192	206	220	232	247	269	169	209	239	265
500 ft. 3-in. Rubber-Lined Cotton Hose. Inside surface very smooth. (Coupling 2½-in. bore, with taper. Inside diam. hose 3-in.)	Noz. Pressure	26	39	52	64	21	26	32	37	42	47	53	63	17	25	33	42
	Height for Fire	45	63	74	81	38	46	55	61	67	72	78	85	32	46	57	69
	Galls. per Min.	150	184	212	235	172	192	212	229	244	258	274	298	192	234	270	304
800 ft. Inferior 2½-in. Rubber-Lined "Mill Hose." Inside surface rough and uneven. (Inside diam. hose and coupling each exactly 2½-in.)	Noz. Pressure	10	14	19	24	7	8	10	11	13	15	16	19	5	7	9	11
	Height for Fire	18	24	33	42	12	15	18	20	23	27	29	34	9	13	17	21
	Galls. per Min.	93	110	128	144	96	106	119	126	140	146	150	164	105	123	139	155
800 ft. 2½-in. Rubber-Lined Cotton Hose. Inside surface very smooth. (Inside diam. hose and coupling each exactly 2½-in.)	Noz. Pressure	13	20	26	33	9	12	14	16	18	21	23	28	7	10	13	16
	Height for Fire	23	35	45	55	17	22	25	29	32	38	41	49	13	19	24	30
	Galls. per Min.	106	132	150	169	116	130	147	150	159	172	180	199	123	148	169	187
800 ft. Standard 2½-in. Rubber-Lined Cotton Hose. Inside surface very smooth. (Diam. coupling 2½-in., but inside diam. hose 2⅝-in.)	Noz. Pressure	15	23	31	38	11	14	17	19	22	25	28	33	8	12	16	20
	Height for Fire	26	40	52	62	20	25	31	34	39	44	49	56	15	23	30	37
	Galls. per Min.	114	141	164	181	126	147	156	164	177	188	199	216	132	162	187	209
800 ft. 2¾-in. Rubber-Lined Cotton Hose. Inside surface very smooth. (Coupling 2½-in. bore, with taper. Inside diam. hose 2¾-in.)	Noz. Pressure	17	26	35	44	13	16	19	22	26	29	32	39	9	14	19	24
	Height for Fire	30	45	58	68	23	29	34	39	46	50	55	64	18	26	35	44
	Galls. per Min.	121	150	174	196	140	150	164	177	192	202	212	234	139	175	204	230
800 ft. 3-in. Rubber-Lined Cotton Hose. Inside surface very smooth. (Coupling 2½-in. bore, with taper. Inside diam. hose 3-in.)	Noz. Pressure	22	32	43	54	17	21	25	29	33	38	42	50	13	19	25	32
	Height for Fire	38	54	67	75	31	38	44	50	56	63	67	75	24	35	46	56
	Galls. per Min.	138	166	193	216	156	172	188	202	216	232	244	266	169	204	234	266

DISCUSSION.

The President. — We have all listened with great interest to Mr. Freeman's paper, and I am certain that he has not given us all the information he has at hand. If any gentleman would like to ask any questions suggested by the paper, I have no doubt Mr. Freeman will be glad to answer them, or if any member wishes to discuss the paper, he can now have an opportunity.

Mr. Tidd. — When Mr. Freeman told us of the discrepancy between the tables of Mr. Ellis and his own experiments, it occurred to me it might be explained in this way: that Mr. Ellis, in getting at the amount of water discharged by his streams, used a meter on the hydrant, — at least he explained to me that was his process of getting at it, — and probably the fifteen to eighteen per cent. the gentleman alludes to represents the obstruction offered by the meter. (Laughter.)

Mr. Jones. — I do not wish to say anything with regard to the scientific portion of Mr. Freeman's paper, but I should like to say a word upon a practical matter which I think should be considered when he speaks of increasing the size of hose to two and three-quarters or to three inches. The old Boston fire department, of which I was a member for a number of years, used only 2-inch leather hose, and the hydrants of the olden time were only two inches at the nozzle outlet. In 1855 the first steam fire-engine came to Boston, from Cincinnati, I think. This steamer used leather hose three inches in diameter. The objection to that was, and it seemed to me as a fireman to be a very serious matter, — you understand that 3-inch leather hose had to be much heavier and stronger than 2-inch, — that it was very inconvenient to handle it full of water on a ladder. That was the objection made at the time. It was, however, quite a jump from two inches up to three inches. It seems to me that 3-inch hose would be a very good thing to use on level ground, when you wanted to supply a hose-tower, or anything of that kind, but I shouldn't want to be one of the men — at my time of life, at any rate — to handle a 3-inch hose on a ladder at the top of a six-story building. (Laughter.)

Mr. Freeman. — I am very glad, indeed, Mr. Jones has called attention to this point, and it is a point I had considered in the paper before the American Society of Civil Engineers. If it proves impracticable to take 3-inch hose up a ladder, then by having the hose-couplings entirely interchangeable it would be a very simple thing, having laid a line of 3-inch hose along the ground, to make on to its end with a short line of 2½-inch unjacketed hose for taking up the ladders and into the building. By a little change in the tactics, this could be arranged all right. Very likely I should not myself feel like dragging a 3-inch hose, filled with water, up a high ladder into a building.

Mr. Jones. — I was going to observe, that with two lines of hose with different sizes that might be arranged. But to use any hose larger than 2½-inch on ladders, unless we have other means of handling the hose than human strength, I think would be a disadvantage.

Mr. Freeman. — Practice gives a more satisfactory demonstration than theory, and so I may state that the city of Pittsburg now has upward of ten thousand feet of 3-inch hose in active use in its fire department, and that they are well satisfied with the change. They take it up ladders, too.

The President. — This question is very pertinent at the present time, in view of the large fires which have recently occurred. I had hoped to have been

able to give you some definite data in regard to the number of streams played and the amount of water used at the Boston fire of November 28. I have not, as yet, been able to get the matter into presentable shape, but I hope to be able to give it later. I think that the quantity of water used and the number of streams played during this last Boston fire was as large as will often be required. I think we may well continue the discussion, perhaps bringing out some of the points with regard to the quantity of water used at fires, and I would ask Mr. Haskell, of Lynn, if he can give us any information with regard to the water supplied at the Lynn fire.

Mr. Haskell. — Mr. President and Gentlemen: A few days ago I received an invitation from Mr. Brackett to be present here and give you some information with regard to the amount of water that was used at the Lynn fire.

The source of supply on which we depend is by four artificial basins formed by dams across brooks, and the water of another brook taken direct by gravitation to the pump well, from which it is pumped into a reservoir by a Leavitt engine of 5,000,000 daily capacity, and a Deane engine of 3,000,000 daily capacity. The distributing pipes are a 16-inch main, a 12-inch high-service main direct to the highlands, which can be turned into the low service before it reaches the highlands, and a 12-inch connection with the force main from the reservoir. At the second alarm the high service was turned on, and as soon as it became evident that a large fire was in progress, the 12-inch gate from the force main was opened. At the time of the first alarm the reservoir contained 20,510,872 gallons, and the Leavitt engine was pumping from the brook supply. In addition to our own supply, the Marblehead Water Company furnished water through a 6-inch pipe. The burnt district was environed and intersected with streets supplied with pipes as follows: One 12-inch, five 10-inch, three 8-inch, four 6-inch, eight 4-inch, provided with 35 hydrants.

While it is impossible to give a definite statement of the number of streams drawing at the same time from any section of pipes, the whole number of engines was 19, and the amount of water used from 12 M. until 6 P.M., was 2,908,477; from 6 P.M. till 6 A.M., 5,373,282; from 6 A.M. to 12 M., 2,827,736, — making a total used in 24 hours of 11,109,495 gallons. Deducting the average daily consumption, we have 8,780,285 gallons as the amount used for the first 24 hours of the fire, — 8,780,285.

The large piles of coal and *débris* left burning in the ruins required a continued use of water through hose from the hydrants amounting to 19,376,984 gallons.

One large waste of water came from the services in the burned buildings; as each building was destroyed, the service was added to the draft on the pipes. Some of the largest services were shut off before the buildings fell.

The stand-pipes put in for insurance purposes are a great source of waste, as the pipes are large, and cannot be shut off as long as they are liable to save the buildings, when in many cases it would be impossible to close the gate. During the progress of the fire no bursts occurred in the pipes, and nothing occurred to interfere with the circulation of the water. (Applause.)

Mr. Shedd. — I was much interested in Mr. Freeman's paper, and I think he has given us a great deal of information on the subject of water supply for fire use. I think, so far as my observations and experiments have extended, they would harmonize entirely with the statements which he has made; and the sug-

gestions which he makes I consider are very valuable indeed. It is a matter of very great consequence to those who own property and to the fire-insurance companies that an ample supply of water should always be ready for use at a fire. The pipes for our modern systems of distribution I think are generally very well devised for fire protection. It costs about half the whole cost of a water system to make it suitable for furnishing water at fires, and very often the revenue does not equal the legitimate cost for that purpose. But a great many of the distribution systems are in an unfortunate condition. A good many lines of pipes across a system of distribution, from the source of supply to nearly the end of the district to be protected, would in many instances be very valuable; and I hope the result of discussions of this sort will be to put a good many distributions into a better condition to be suitable for use in putting out large fires than they are in now.

Mr. Hawes. — I would like to ask Mr. Haskell whether there was water enough at the Lynn fire, or whether they were troubled with lack of supply?

Mr. Haskell. — I do not think there ever was a large fire of that sort when any one would say there was water enough, even if enough was used to flood the district ten or fifteen feet deep.

Mr. Hawes. — It strikes me the idea which was suggested of using two sizes of hose at a fire is a little impracticable. At most fires I have attended the firemen are apt to be in a hurry, and they wouldn't be likely to stop at the foot of a ladder and hunt around after a 2½-inch hose to couple on. They would go right up with it, I guess, no matter what size the hose was. I think they would take it up if it was five inches, and they had to put a man on every round of the ladder. (Laughter and applause.) I never saw firemen at a fire but once when there wasn't any hurry, and that was down at Nantucket. There happened to be sixteen of us down there one day who belonged to Cataract No. 3, of Fall River, when there was an alarm of fire, and when the machine went by we saw it was Cataract No. 3, and so we all took hold and went to the fire. (Laughter.) When we got there we found it was a barn. A ladder was put up, and one of our men took an axe, when the owner of the barn rushed up and said: "Don't, don't cut that door! Wait a minute and I will get a screw-driver, and you can take the hinges off." (Laughter.) This is the only fire I ever went to when they were not in a hurry.

Mr. Haskell. — Mr. Hawes' remarks lead me to think that perhaps the firemen at Lynn had ample time in those cases Mr. Freeman spoke of, where they had run 2,000 feet of hose. They must have gone by a number of hydrants before they attached their hose, for I think there was no place where they could have gone 500 feet without finding a hydrant.

Mr. Winslow. — I would like to ask Mr. Freeman in what way this friction loss in hose was determined; in other words, how the hose was laid, — whether it was laid straight, or laid as it naturally would be by the fire department. The reason why I ask this question is that Ellis' book is considered as authority by the firemen in my place, and you say he is in error about eighteen per cent. I don't know in his case whether the hose was laid as firemen would lay it, or whether it was laid for the experiment, and that is the reason I ask you how yours was laid.

Mr. Freeman. — The point in which I referred to Ellis as being eighteen per

cent. in error was in relation to the number of gallons discharged per minute, not in relation to the friction loss in the hose. In determining the amount of pressure lost by friction in the hose, I experimented with the hose straight, and also with the hose crooked, just as the firemen would lay it, and found that between laying it straight and laying it in a serpentine form there was a difference of about six per cent. in the amount of pressure lost by friction.

NEW ENGLAND WATER WORKS ASSOCIATION.

ORGANIZED 1882.

Vol. IV. June, 1890. No. 4.

This Association, as a Body, is not responsible for statements or opinions of any of its members.

FEBRUARY MEETING.

Young's Hotel, Boston, Feb. 12, 1890.

An adjourned meeting of the Association was held on Wednesday, February 12, at Young's Hotel. President Brackett sat at the centre of the head table, and the following-named members were present: —

Solon M. Allis, Superintendent, Malden, Mass.
Geo. E. Batchelder, Registrar, Worcester, Mass.
Joseph E. Beals, Clerk and Registrar, Middleboro', Mass.
Dexter Brackett, Superintendent Eastern Division, Boston, Mass.
Geo. F. Chace, Superintendent, Taunton, Mass.
R. C. P. Coggeshall, Superintendent, New Bedford, Mass.
Byron I. Cook, Superintendent, Woonsocket, R.I.
F. H. Crandall, Superintendent, Burlington, Vt.
Lucas Cushing, Assistant Superintendent, Boston, Mass.
Edwin Darling, Superintendent, Pawtucket, R.I.
Thos. M. Drown, Professor Chemistry, Institute Technology, Boston, Mass.
Desmond FitzGerald, Superintendent Western Division, Brookline, Mass.
F. F. Forbes, Superintendent, Brookline, Mass.
Z. R. Forbes, Assistant Superintendent, Brookline, Mass.
Frank L. Fuller, Civil Engineer, Boston, Mass.
Albert S. Glover, West Newton, Mass.
J. A. Gould, Jr., Assistant Engineer, Boston, Mass.
John L. Harrington, Cambridge, Mass.
William M. Hawes, Water Commissioner, Fall River, Mass.
Horace G. Holden, Superintendent, Nashua, N.H.
John C. Haskell, Superintendent, Lynn, Mass.
Patrick Kieran, Superintendent, Fall River, Mass.
Wilbur F. Learned, Assistant Engineer, Boston, Mass.
Hiram Nevons, Superintendent, Cambridge, Mass.
Albert F. Noyes, City Engineer, West Newton, Mass.
F. H. Parker, Commissioner, Burlington, Vt.
Dwight Porter, Assistant Professor C. E., Institute Technology, Boston, Mass.
G. J. Ries, Superintendent, East Weymouth, Mass.

W. W. Robertson, Registrar, Fall River, Mass.
A. H. Salisbury, Superintendent, Lawrence, Mass.
Chas. W. S. Seymour, Superintendent, Hingham, Mass.
Solon F. Smith, Superintendent, Grafton, Mass.
Lucien A. Taylor, Civil Engineer and Contractor, Boston, Mass.
M. M. Tidd, Hydraulic Engineer, Boston, Mass.
Chas. K. Walker, Superintendent, Manchester, N.H.
W. H. Vaughn, Superintendent, Wellesley Hills, Mass.
Herbert F. Whittier, Registrar, Lawrence, Mass.
Horace B. Winship, Civil Engineer, Norwich, Conn.
Geo. E. Winslow, Superintendent, Waltham, Mass.
E. T. Wiswall, Water Commissioner, West Newton, Mass.
Millard F. Wright, Superintendent, Lowell, Mass.
Hon. E. R. Jones, Boston, Mass.
F. W. Shepherd, "Fire and Water," New York.
A. W. Worthley, American Frost Meter, Boston, Mass.
A. H. Brodrick, Chadwick Lead Works Co., Boston, Mass.
E. L. Ross, Chapman Valve Co., Indian Orchard, Mass.
F. H. Hayes, Dean Steam Pump Company, Holyoke, Mass.
W. D. Gorham (Gilchrist & Gorham), Boston, Mass.
W. H. Gallison, Pipe and Fittings, Boston, Mass.
H. D. Winton, Hersey Meter, South Boston, Mass.
J. A. Tilden, Hersey Meter, South Boston, Mass.
Henry F. Jenks, Fountains, Pawtucket, R.I.
Sumner & Goodwin, Pipe and Fittings, Boston, Mass.
John K. Otis, Union Water Meter, Worcester, Mass.
B. Frank Polsey, Walworth Manufacturing Company, Boston, Mass.
G. L. Whittemore, Geo. Woodman & Co., Boston, Mass.
J. M. Betton, H. R. Worthington Co., New York City.

GUESTS.

John M. Jordan, Water Commissioner, Malden, Mass.
Walter Clifford, Mayor, New Bedford, Mass.
Wm. T. Sedgwick, Professor, Massachusetts Institute Technology, Boston, Mass.
Mr. Hunnewell, Water Commissioner, Brookline, Mass.
Robert Grant, Chairman Water Board, Boston, Mass.
W. E. Webber, Water Board, Boston, Mass.
R. J. Flynn, Water Board, Boston, Mass.
E. S. Sullivan, Superintendent Mystic Division, Boston, Mass.
Mr. McCormick, Water Commissioner, Lawrence, Mass.
Bert J. Getchell, Clerk, New London, Conn.
F. B. Webster, Wellesley Hills, Mass.
E. LeBaron, Commissioner, Middleboro', Mass.
Ralph W. Cook.
A. F. Salmon, } Lowell Water Board.
Mr. Holt, }
S. A. Welch, Worcester, Mass.

After dinner had been served the meeting was called to order by the President, and the Secretary presented the following names of applicants for membership: —

RESIDENT ACTIVE MEMBERS.

P. F. Babbidge, Superintendent, Keene, N.H.

Robert Grant, Chairman Water Board, Boston.

E. P. LeBaron, Chairman Water Board, Middleboro'.

Wm. B. Littlefield, Water Commissioner, Lynn.

Wm. T. Sedgwick, Professor Biology, Mass. Institute Technology, Boston, Mass.

Eugene S. Sullivan, Superintendent Mystic Division, Boston.

NON-RESIDENT ACTIVE MEMBERS.

B. F. Steben, Manager Water Company, Brockville, Ontario, Canada.

HONORARY MEMBER.

F. W. Shepherd, Editor "Fire and Water," New York City.

On motion of Mr. Hawes, the Secretary was instructed to cast the ballot of the Association for the above-named gentlemen, which he did, and the President announced their election as members of the Association.

There being no other matter of business to come before the meeting, the President introduced Mr. F. F. Forbes, Superintendent of the Water Works at Brookline, who read a paper entitled "A Study of Algæ Growths in Reservoirs and Ponds."

QUARTERLY MEETING.

Young's Hotel, Boston, March 12, 1890.

The following guests and members of the Association were present: —

Active Members: — Frank A. Andrews, Assistant Superintendent, Nashua, N.H.; Charles F. Allen, Treasurer, Hyde Park, Mass.; Solon M. Allis, Superintendent, Malden, Mass.; P. F. Babbidge, Superintendent, Nashua, N.H.; Geo. E. Batchelder, Registrar, Worcester, Mass.; John G. Brady, Commissioner, Worcester, Mass.; Joseph E. Beals, Clerk, Middleboro', Mass.; A. P. Barrett, Registrar, Woburn, Mass.; Dexter Brackett, Superintendent, Boston, Mass.; George F. Chace, Superintendent, Taunton, Mass.; F. H. Crandall, Superintendent, Burlington, Vt.; R. C. P. Coggeshall, Superintendent, New Bedford, Mass.; Byron I. Cook, Superintendent, Woonsocket, R.I.; Lucas Cushing, Assistant Superintendent, Boston, Mass.; Charles E. Chandler, City Engineer, Norwich, Conn.; P. F. Crilly, Superintendent, Woburn, Mass.; John W. Ellis, Water Commissioner, Woonsocket, R.I.; F. F. Forbes, Superintendent, Brookline, Mass.; E. E. Farnham, Superintendent, Sharon, Mass.; Melvin C. French, Superintendent, South Braintree, Mass.; Frank L. Fuller, Civil Engineer, Boston, Mass.; L. E. Forbes, Assistant Superintendent, Brookline, Mass.; Albert S. Glover, West Newton, Mass.; John A. Gould, Jr., Assistant Engineer, Boston, Mass.; E. A. W. Hammatt, Civil Engineer, Boston, Mass.; William F. Harbach, Water Commissioner, Newton Centre, Mass.; William

M. Hawes, Water Commissioner, Fall River, Mass.; Horace G. Holden, Superintendent, Nashua, N.H.; Horatio N. Hyde, Jr., Superintendent, Newtonville, Mass.; Patrick Kieran, Superintendent, Fall River, Mass.; E. P. LeBaron, Chairman Water Board, Middleboro', Mass.; W. F. Learned, Civil Engineer, Boston, Mass.; James W. Morse, Superintendent, Natick, Mass.; Hiram Nevons, Superintendent, Cambridge, Mass.; A. F. Noyes, City Engineer, West Newton, Mass.; Weaver Osborne, Commissioner, Fall River, Mass.; Daniel Russell, Everett, Mass.; George J. Ries, Superintendent, East Weymouth, Mass.; Walter H. Richards, Superintendent, New London, Conn.; L. Fred Rice, Civil Engineer, Boston, Mass.; George A. Stacy, Superintendent, Marlboro', Mass.; W. T. Sedgwick, Professor Biology, Massachusetts Institute Technology, Boston, Mass.; B. F. Steben, Manager, Brockville, Canada; A. H. Salisbury, Superintendent, Lawrence, Mass.; Chas. W. S. Seymour, Superintendent, Hingham, Mass.; Lucian A. Taylor, Civil Engineer, Boston, Mass.; Joseph G. Tenney, Superintendent, Leominster, Mass.; W. H. Vaughn, Superintendent, Wellesley Hills, Mass.; F. W. Whitlock, Civil Engineer, Waterbury, Conn.; Millard F. Wright, Superintendent, Lowell, Mass.; G. E. Winslow, Superintendent, Waltham, Mass.; E. T. Wiswall, Commissioner, West Newton, Mass.

Associate Members: — J. H. Coggeshall and C. H. Hobson, of H. R. Barker Manufacturing Co., Lowell, Mass.; James M. Betton, Boston, Mass.; E. G. Ross, of Chapman Valve Manufacturing Co., Indian Orchard, Mass.; J. A. Mitsch, of W. H. Gallison, Boston, Mass.; J. A. Tilden and W. B. Winton, Hersey Meter Co., South Boston, Mass.; Henry F. Jenks, Pawtucket, R.I.; John C. Kelley, National Meter Co., New York City; Walter B. Nye, Warren Filter, Boston, Mass.; F. E. Stevens, Peet Valve Co., Boston, Mass.; George Ross and E. C. Woodward, Troy, N.Y.; G. A. Polsey, Sumner & Goodwin, Boston, Mass.; W. H. Moulton, Union Water Meter Co., Worcester, Mass.; E. L. Abbott, Water Waste Prevention Co., New York; B. F. Polsey, Walworth Manufacturing Co., Boston, Mass.; G. L. Whittemore, Geo. Woodman & Co., Boston, Mass.; A. A. Blossom, Whittier Machine Co., South Boston, Mass.

Guests: — Mayor H. M. Burr, Newton, Mass.; A. S. Rich, Hingham, Mass.; James T. Murphy, Commissioner, Marlboro', Mass.; Frank Wall, Marlboro', Mass.; M. D. Dexter, Norwich, Conn.; Thomas Rogers, Nashua, N.H.; E. A. Stevens, Jr., Commissioner, Malden, Mass.; Edmund Brown, East Weymouth, Mass.; E. A. Corey, Boston, Mass.; W. L. Goddard, Boston, Mass.; W. B. Hawes, Fall River, Mass.; E. Severy, Waterbury, Conn.; W. F. Whittemore, Leicester, Mass.; M. N. Boardman, Worcester, Mass.

After dinner had been served, President Brackett called the company to order, and the Secretary presented the applications of the following-named persons for membership, they having been duly approved by the Executive Committee: —

Resident Active: — Walter Clifford, President Water Board, New Bedford, Mass.; F. Floyd Weld, City Engineer, Waterbury, Conn.; P. F. Crilly, Superintendent, Woburn, Mass.; A. P. Barrett, Registrar, Woburn, Mass.; A. E. Brown, Assistant Superintendent, Milford, Mass.

Non-Resident Active: — Reuben Shirreffs, 2d Assistant Engineer East Jersey Water Co., Paterson, N.J.; M. O'Connor, Superintendent, Bayonne, N.J.

Associate: — W. T. Montgomery, Agent Providence Steam & Gas Pipe Co.,

Boston; W. J. Ranton, Superintendent Porter Manufacturing Co., Syracuse, N.Y.; E. B. Williams, Steam, Gas, and Water Valve, Boston, Mass.

On motion of Mr. Hawes the Secretary was instructed to cast the ballot of the Association for the gentlemen named, which he did, and the President declared them to have been elected members.

The PRESIDENT. — The Secretary has one other matter from the Executive Committee to present.

The SECRETARY. — The Executive Committee has considered the matter of amending Art. 3 of our Constitution and By-Laws, which relates to initiation fees and dues, so that it shall read as follows: "Section 2. That the regular annual dues of members shall be as follows, payable in advance: For active members, $2; for associate members, $10." The Executive Committee recommend that that amendment be made.

Mr. NOYES. — Some of us do not have the By-Laws; will the Secretary be good enough to read the article as it now stands?

The PRESIDENT. — The article now provides "that the regular annual dues of members shall be as follows: For active members, $2; for associate members, $5." The change is from $5 to $10 for the annual dues of the associate members.

On motion of Mr. Hawes, the amendment was unanimously adopted.

The PRESIDENT. — I will take this opportunity to say that this will probably be the last meeting before the annual meeting, which will be held at Portland on the 11th, 12th, and 13th of June; and I hope all who are here will endeavor to attend that meeting. We certainly have had a very encouraging attendance at all the meetings this winter. I have been very much gratified by the large attendance which we have had at all of our meetings, and also by our gain in membership. The membership a year ago was 282. Since that time, including those who have been elected to-day, there have been 57 new members elected, making our membership at present 337, which I think is considerably in excess of the membership of the American Association.

Mr. HOLDEN. — Before adjournment I would like to call the attention of this meeting to the Convention of the American Water Works Association, which is to be held in Chicago, commencing May 20th, and lasting three days. This organization, as you are aware, is composed of representative men from all the principal water works throughout the country; and, although the programme of arrangements is not yet complete, I am confident this will be the largest and most successful as well as the most interesting gathering of water-works officials we have ever had. In behalf of the American Association I wish to extend an invitation to all the members of this Association to meet with them at Chicago.

The PRESIDENT. — I will take this opportunity to call your attention to the subject of the exchange of sketches, which it has been our custom to have at the annual meeting; and I do it this time in order that you may all have it in mind, because between now and the middle of June you will have plenty of time to prepare something. For fear that some may not understand exactly what this means, I will state that each member is desired to contribute from 50 to 100 copies of a sketch on some subject, the sketch either to be prepared by blueprint or any other well-known duplicating process, and to illustrate tools or devices, or anything which you think will be of interest to other members of the

Association. They are all to be prepared of a uniform size, 10 × 15 inches. I trust that a large number of sketches will be presented at the meeting in Portland.

On motion of Mr. Hawes, the President appointed Messrs. Whitney, of Newton, Robertson, of Fall River, and Batchelder, of Worcester, a committee to consider and report to the Association, at its annual meeting, upon "A Proper Basis for the Establishment of Water Rates."

The following-named papers were then read and discussed: "Method of Cleaning the Distributing Reservoir of the New Bedford Water Works," by R. C. P. Coggeshall, Superintendent, New Bedford, Mass.; "Experience with a Thirty-Inch Gate," by Hiram F. Nevons, Superintendent, Cambridge, Mass.; "Inequalities in Water Rates," by Horace G. Holden, Superintendent, Nashua, N.H.; "An Experience in Excavating in Quicksand," by Albert F. Noyes, City Engineer, Newton, Mass.; "Artesian Well Experiment at Taunton, Mass.," by George F. Chace, Superintendent, Taunton, Mass.

Adjourned.

NOTES ON LAYING A TWENTY-INCH MAIN.

A Paper read before the Association, January 8, 1890.

BY

Walter H. Richards, Supt. Water Works, New London, Conn.

Mr. Richards. — Mr. President, at the Springfield meeting there was a committee appointed to report on the thickness of cast-iron pipe, and at the Providence meeting there was a committee appointed to report on special castings. I believe neither of these committees has ever reported, and it is mainly for the purpose of trying to bring about a discussion on these important subjects that I present the following notes on the laying of a 20-inch cast-iron pipe in New London.

The main in question was designed to increase the supply to the city of New London. It was 5 miles long, and laid generally parallel to a 16-inch cement-lined wrought-iron pipe, and at a distance of from 8 to 200 feet therefrom.

The pipe was divided into two classes; Class A was used for heads of from 20 to 50 feet, was 63-100th inches thick, and weighed 138 pounds to the foot. Class B, for heads of 50 to 160 feet, was 70-100th inches thick, and weighed 154 pounds to the foot. It was necessary to cart the pipe over very rough roads from 2 to 6 miles, and these thicknesses were decided upon with due consideration of the effects of transportation, but lighter than is generally used for work of this kind. The pipes were subjected to rigid inspection at the foundry, and of the total number cast 10% were rejected. Of the total number accepted at the foundry about 7% were broken in transportation or handling, or by blasting; a large majority of the breaks being checks running 2 or 3 inches from the spigot end. The percentage of cracked pipe was about the same for each class of pipe.

The bells were of a design similar to the Providence bell, being 3¾ inches deep, with ⅜-inch joint room, taking about 27 pounds of lead for each joint.

The pipe was laid on perfectly straight lines and nearly straight grades, all changes in direction being made with bends of 20 feet radius. Bends of three different lengths were used, and the angles in the line arranged to take one or a combination of two or more of these specials at each angle.

Before the pipe was covered it was tested by making a 2-inch connection with the old main, the open end of the pipe being stopped with a wooden plug bolted in. By this method any defect in caulking was discovered and remedied at once, and it is thought that many small-joint leaks that never would have shown above ground were thus prevented. It is believed that the little trouble and expense occasioned by the test were justified by a considerable saving in repairs, as but two small joint-leaks and two cracked pipes were found in the final test, one of the pipes being cracked by a cave in the bank during the filling of the trench.

The PRESIDENT. — If this paper will bring about any discussion on the question, as Mr. Richards suggests, of the thickness of pipe that is necessary, and also on the subject of designing special castings, as it certainly ought to, I think it will be of value to the Association. The paper is now open for discussion, and I should be very glad to hear from any members.

Mr. JONES. — The first 20-inch pipe laid in Boston, when they knew but little about them, to be sure, weighed about 200 pounds to the foot, and was nearly seven-eighths of an inch thick, — a little over three-quarters. If a mistake was made, it was made on the safe side. I can only speak in general terms about such things, but I think there are two things with regard to laying water-pipes that are open to criticism: one is that they do not make them thick enough, and the other that they do not make them large enough.

Mr. HAWES. — Mr. Richards stated that, with regard to the thickness of the pipe, they took into consideration the carting of it six miles. How thin or how thick would a pipe have to be to shake to pieces in carting six miles? (Laughter.)

Mr. RICHARDS. — That is the only consideration, really, that governed, because the pipe might be very much thinner and still stand the pressure; it is only to provide against transportation that you make them heavy.

Mr. JONES. — When the gentleman speaks about its being thick enough to stand the pressure, even if it were thinner than that, does he take into consideration the fact that the pipe is liable to decay, and does he take into consideration the question of water-hammer?

Mr. RICHARDS. — The pipe in question was for a supply main without any taps off of it, and the water-hammer on it would be comparatively small to what it would be in a distribution pipe in the city.

Mr. JONES. — I cannot agree with the gentleman there, because the first 30-inch main in Boston burst with the water-hammer from the fountain playing on the Common, and it was quite a serious break. Another break was on the top of the hill, from the water-hammer. The pressure then in Boston, I believe, was only about 50 pounds to the square inch.

Mr. FULLER. — I would like to ask Mr. Richards if he couldn't have got his curves with straight pipe, if he had sufficient radius, without using specially cast pipe.

Mr. RICHARDS. — Yes, they could have been made with straight pipe, but

the joint room, three-eighths of an inch, would have necessitated a very large radius.

Mr. Darling. — You have the short bell, and you cannot make a curve in them; with a longer bell you could curve your pipe more.

The President. — I suppose there is no question but that the thickness of pipes in general use is larger than is necessary to withstand the static pressure; but the constant tendency at the present time is, I think, toward increase of pressure, on account of increased heights of buildings, and on account of the water-hammer, due to the increased use of water elevators. The pressure on the pipes is in many cases increased very much beyond what they originally were designed to withstand. In Boston we have large sections of the city where the pipes laid in 1848, when there was a pressure of perhaps 40 pounds, are to-day, by the substitution of high service, withstanding a pressure of from 90 to 100 pounds, to say nothing of the additional pressure due to the water-hammer. I think the increasing tendency in this direction must be considered by any one who is designing a system of water-supply.

Mr. Darling. — I want to say just a word. I think the greatest mistake that is made by a great many towns and cities to-day is, that they try to economize too much in putting in not only light pipe, but in putting in small-sized pipe. As our President has remarked, there is a constant tendency toward an increased use of the water. In the first place, take the hydrant service. That is one of the greatest and most important features of any water works, to say nothing about the family use. Then when you come to take on this new feature, which the insurance companies have brought up by the introduction of the automatic sprinklers, you have got to provide for that in addition. Then, too, there are the elevators, and a general increase in the use of water for all purposes, and you must have large pipes to get such a service as you want. So I say that the greatest mistake to-day is, that cities and towns do not put in pipes large enough to provide for the growth there is sure to be in the years to come. They are too careful, too economical, too prudent. They should put in larger-sized pipes and pipes of good thickness. Now, when you speak of water-ram, you don't know what circumstances will produce it. There are to-day, with these new complications, ten chances that you will get a water-ram where there was not one years ago. With the elevators and sprinklers, you do not know what minute you are going to be called upon to furnish an excessive supply of water at some particular point, and that is controlled by the parties themselves; and they do not stop to think whether they should not take time enough in shutting off the water, but they are liable to shut it off immediately; and if they do shut it off immediately, you are going to get a water-ram; you cannot help it.

Mr. Jones. — One word more. Our President neglected or forgot to mention something with regard to the decay of water-pipes in Boston. Boston, to be sure, is on the seaboard; fortunately not all water-works are so situated; and a good many pipes here are laid in ground that has been filled in from the docks with dock mud. In ten years after the water works were laid here, 12-inch pipes, that were nearly five-eighths of an inch thick, were so damaged by this dock mud that you could cut them with a knife as you cut a lead-pencil; and they are taking them out every week now, I suppose, that you can cut in the same way. So, certainly, it is policy in Boston to use pipe large enough to resist,

for a reasonable time, such influences. It may be that is something which does not have to be taken account of in the country, but, nevertheless, if I was to lay pipes again, I should try to make a mistake in the direction of laying large pipes.

Mr. Tidd. — I believe, with the gentleman who has last spoken, that the thickness of pipe should be governed somewhat by where it is to be put. I have no doubt that in a soil such as he speaks of, a thicker pipe would be required than, perhaps, would be required in a different soil. But with the soils which we usually meet in building water works through the country, my impression is we have been using unnecessarily large pipe. My attention has been called to that particularly by reading the reports of tests at the Watertown Arsenal. The breaking strain of a 16-inch pipe, I think 44-100ths of an inch thick, was about 4,800 feet head. Now, it seems to me we might get along with one-half that, for probably the water-hammer never would come up to twenty-five per cent. of it. In the early stages of water-works construction it was customary to use very thick pipe, but I think the experience we have had lately will warrant us in using thinner pipe in many places. I have always believed in the principle of prevention of water-ram wherever possible. I don't believe that shutting off a 4-inch pipe with a valve should ever be allowed. I think that will break any pipe. It seems to me, as I have said before, we have been wasting a great deal of iron. I agree with the gentleman who has last spoken as to the size of the pipes. I never knew a pipe too large, but I have seen lots of them too small.

Mr. Gowan. — I would like to ask if the quality of the iron may not have considerable to do with the question, and the manner in which it is cast; and if there is any way in which a man not familiar with pipe casting can tell whether or no he is getting a good pipe.

Mr. Tidd. — My remarks were based on the supposition that good iron is used. We generally specify that the iron shall not be less than 10,000 pounds tensile strain, and the pipe should be cast on end, bells out. Of course, if we are going to use pot-metal, the weight I suggest would not be sufficient. (Laughter.)

Mr. Richards. — Of course I wouldn't advocate the use of a thin pipe, if you are not going to inspect it. If you are going to take any pipe the foundry will send you, I should advise you to have it as thick as they will make it.

Mr. Tidd. — A foot, at least.

Mr. Richards. — This pipe we used was very carefully inspected, and was tested to 300 pounds pressure at the foundry, and hammered by my own inspector, and for that reason I think it is plenty strong enough.

The President. — The question has been brought up in the discussion of Mr. Richards' paper as to the sizes of pipes required for fire service, and as the discussion has seemed to run somewhat in that channel, I will take the liberty of reading a few notes that I have made with regard to the water-supply at the Thanksgiving fire in Boston, which may bear somewhat on the question of the necessary sizes of pipes.

WATER-SUPPLY AT THE BOSTON FIRE OF NOVEMBER 28, 1889.

The daily papers have given very complete details of the fire which occurred in Boston on November 28, but the question of the water-supply is, I think, worthy of our further consideration. The accompanying plan shows the outlines of the burned district, the sizes of the pipes, and the location of the hydrants. The accompanying table gives the steamers in service at the fire, their location, hours in service, quantity per minute, and approximate total quantity thrown on the fire by each steamer.

The total number of engines engaged at the fire was 56, of which number two were destroyed by falling walls soon after the fire began, and two — 16 and 18 — broke down after a few hours' service; so that the total number of steamers in service at any time did probably not exceed 52, and the number of streams thrown on the fire at any time, including five streams thrown by fire pumps of R. H. White & Co. and Hovey & Co., was not more than 86, and was probably somewhat less. The approximate quantity of water used per minute was 20,000 gallons, or at the rate of 28,800,000 gallons per day. The total quantity used on the fire during the first twenty-four hours was about 14,000,000 gallons. Seven hydrant streams were thrown on the ruins from November 29 to December 4, when the number was reduced to 4, and on December 11 the streams were all shut off. The quantity of water used by the hydrant streams during the twelve days was about 10,000,000 gallons, making a total of 24,000,000 gallons used on the fire, exclusive of leakages from services in the burned buildings. As the area of the burned district, including streets, was about 150,000 square feet, the water used during the first twenty-four hours would have covered the entire district to a depth of twelve and one-half feet.

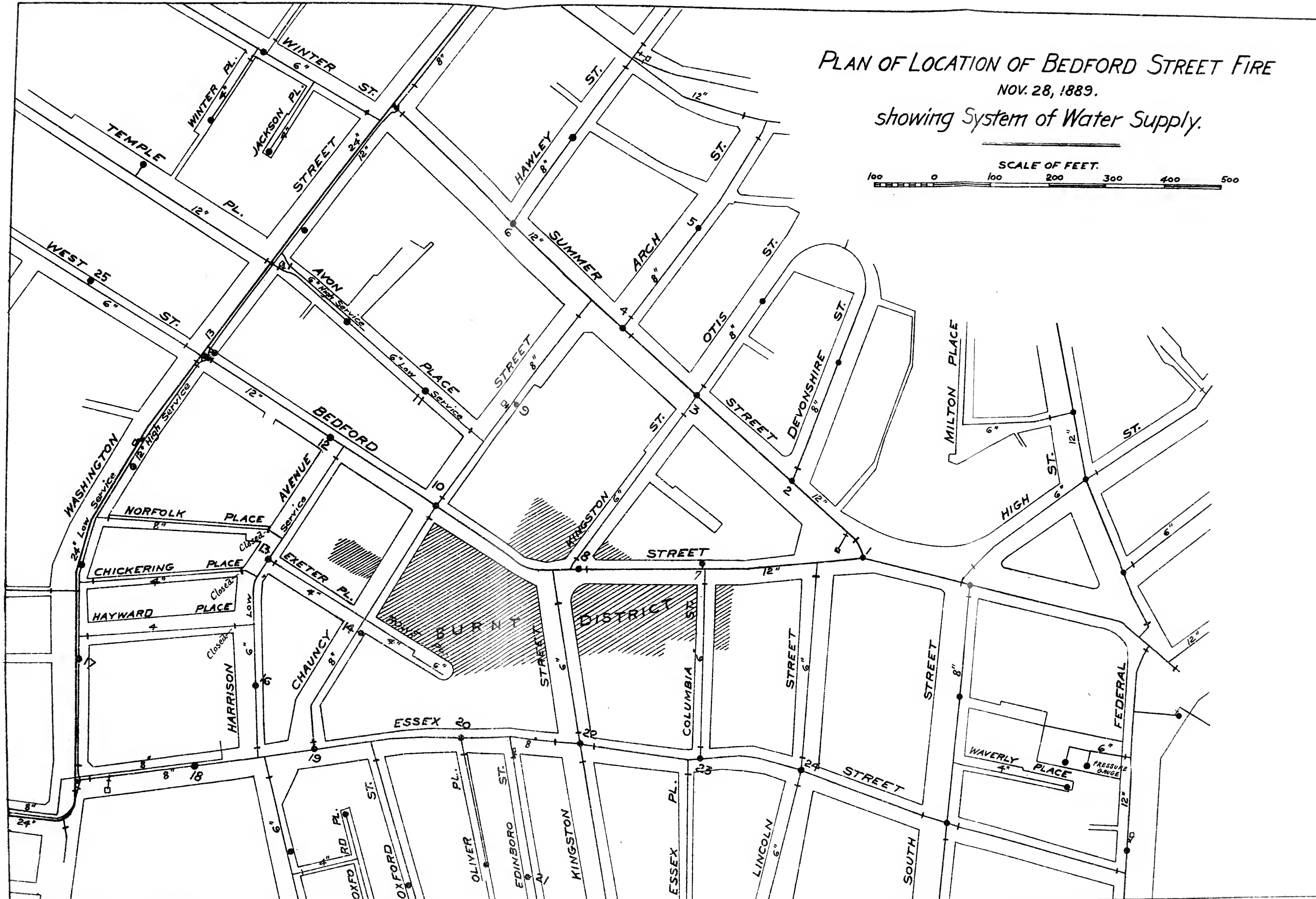
An inspection of the plan shows that this water was all taken from 25 hydrants, most of which were supplied from the line of pipe in Summer, Bedford, and Essex streets. These pipes were 12 inches in diameter in Summer and Bedford streets, and 8 inches in diameter in Essex street, and they were supplied by a 24-inch main in Washington street, aided by 6 and 8 inch cross mains connecting with 12-inch mains in Beach and Franklin streets. That the supply was ample was shown by the reports of the fire department, and also by the fact that during the progress of the fire water could be drawn from the service pipes at the top of buildings in the burning district.

A recording gauge at the water-works office, near the foot of Summer street, showed a minimum pressure of 30 pounds, or about 10 pounds less than the ordinary pressure at that point.

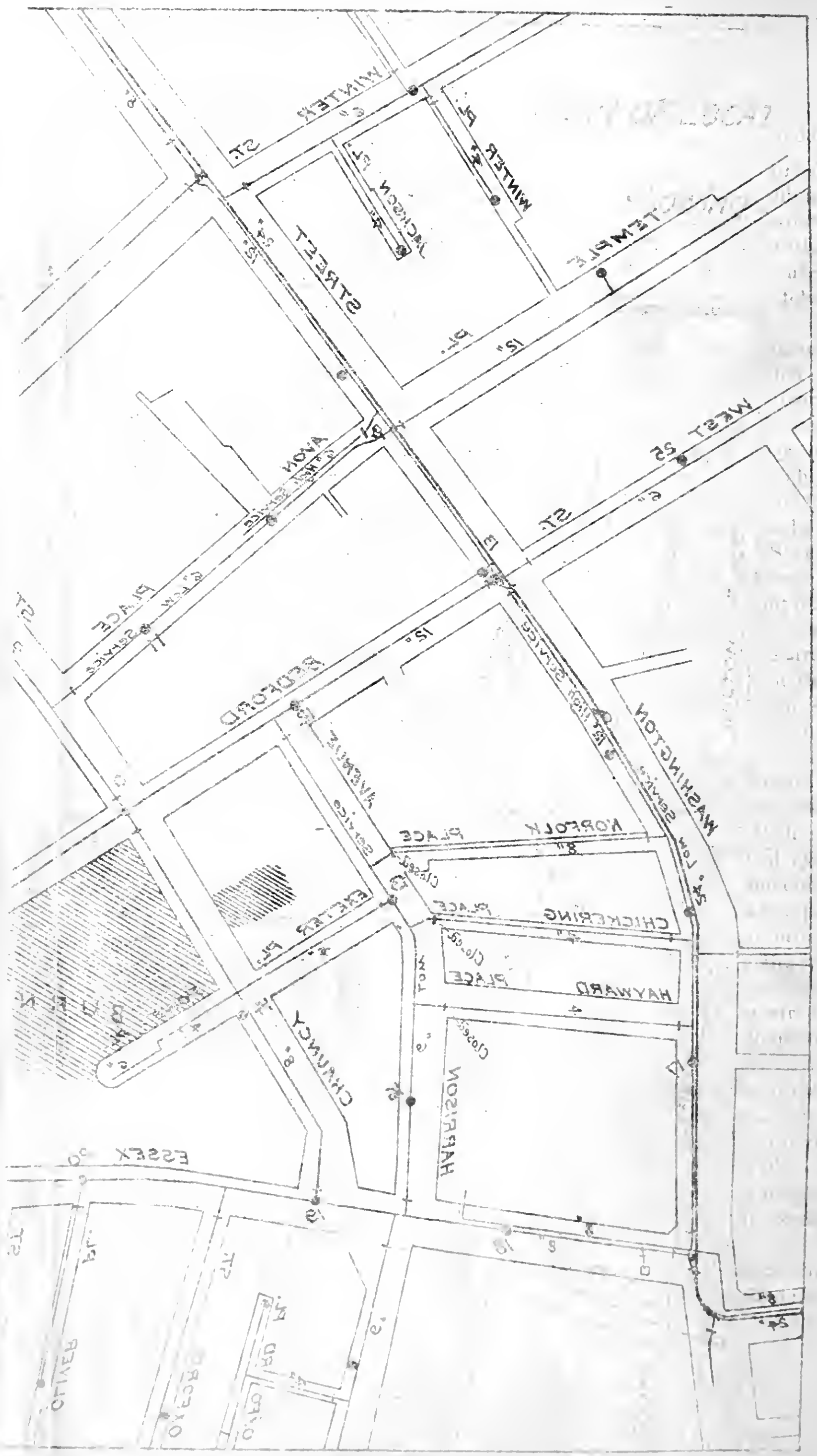
It appears to me that from the above data some conclusions may be drawn which will be of value. Mr. Sherman, in a paper read before this Association in December, 1888, presented such data as he was then able to collect with regard to the quantity of water used at large fires, and from the data collected drew the conclusion that 200,000 gallons per hour was an ample supply for fire service, and that the total quantity for twenty-four hours would not exceed 2,000,000 gallons.

In discussing Mr. Sherman's paper, Mr. Shedd, of Providence, suggested the use of the following formula in determining the number of streams required: —

$$\text{Number of streams} = \sqrt{\text{population} \times .005}$$



PLAN OF LOCATION OF BEDFORD STREET FIRE
NOV. 28, 1889.
showing System of Water Supply.
SCALE OF FEET.
100 0 100 200 300 400 500
THE BURNT DISTRICT
WINTER ST.
TEMPLE PL.
WINTER PL.
JACKSON PL.
WEST ST.
WASHINGTON
HAWLEY ST.
SUMMER
ARCH
OTIS ST.
DEVONSHIRE ST.
AVON PLACE
BEDFORD
STREET
KINGSTON ST.
NORFOLK PLACE
CHICKERING PLACE
HAYWARD PLACE
HARRISON
AVENUE
EXETER PL.
CHAUNCY
ESSEX
COLUMBIA
MILTON PLACE
HIGH ST.
FEDERAL
WAVERLY PLACE
PRESSURE GAUGE
OXFORD ST.
OLIVER PL.
EDINBORO ST.
KINGSTON
ESSEX PL.
LINCOLN
SOUTH



WINTER ST.
WINTER PL.
JACKSON PL.
TEMPLE PL.
STREET
WEST ST.
AVON PLACE
BEDFORD
WASHINGTON
NORFOLK PLACE
CHICKERING PLACE
HAYWARD PLACE
EXETER PL.
CHAUNCY
HARRISON
ESSEX

This would give about 45 streams as the number necessary for Boston, or about one-half the number used on November 28, and Mr. Sherman's results must be multiplied by six to equal the amounts used in Boston.

The area covered by the fire was small, and I see no reason why a similar fire should not be liable to occur in any smaller city containing high buildings on narrow streets.

Another point worthy of notice is the advantage which was derived from the use of the hydrants of the Lowry pattern, which are used throughout the business section of the city. Had the hydrants been of the Post pattern, located in the sidewalk, it would not have been practicable to so place 54 steamers that none should be more than 600 feet distant from the fire. These hydrants have barrels 9 inches in diameter, placed directly over the mains, at junctions of streets where practicable, and many of them supplied eight streams or 2,000 gallons per minute.

When we consider that a steamer playing through 400 feet of hose and 1⅛-inch nozzle, with 100 lbs. water-pressure, will discharge 240 gallons per minute, while with 1,000 feet of hose the discharge will be but 170 gallons, and the effective height of the streams will be respectively 65 and 36 feet, it is very evident that it is of great advantage to have the steamers placed as near the fire as safety will permit. Post hydrants are preferable for use in districts not thickly settled; but more than two steamers cannot be conveniently attached to one at the same time.

Another advantage of the Lowry or other pattern of flush hydrant is that it is less liable to be broken by falling walls.

I wish to call your attention to the danger to the water-supply from this cause. Many buildings in Boston, and I think in other cities, are provided with "fire pipes," — pipes three or four inches in diameter, connected with the street main, carried into the building, with hose connections on the different floors, to be used in case of fire, or in other cases connected with systems of automatic sprinklers.

Consider the effect on your water-supply if the falling walls of burning buildings break off a number of these pipes, and at the same time fill the street with brick, granite, and iron, so that it is an impossibility to reach the shut-off valves.

Without underestimating the value of these pipes as a means of fire protection, I am of the opinion that the water-supply in the street mains should not be jeopardized in any manner. Even then it is not always secure. The falling walls broke completely off the 12-inch pipe on Bedford street, but fortunately the ends of the pipe did not separate, and the leakage was not large enough to affect the supply. More than a week elapsed before it could be repaired, on account of dangerous walls and the mass of brick and stone which filled the street.

At the time of the great fire of November, 1872, the number of steamers owned by the city was 21, and 45 engines from outside cities assisted the Boston department. The fire of 1872 covered an area of 65 acres.

In conclusion, I desire to call your attention to the constantly increasing demands for water which must be considered in designing systems of pipe distribution.

The consumption *per capita* for manufacturing purposes is constantly in-

creased by the demand for water elevators, electric lighting, etc. The fire departments are increasing the capacity of their engines, and the result will be that our pipe systems will in a few years require enlarging to meet these demands.

Steamer.	Location of Steamer.[1]	Hours in Service.	Number of Streams Played.	Gallons per Minute.	Total Quantity Thrown on Fire, Gallons.	Remarks.
Boston, No. 1 . . .	2	21	2	460	579,600	
Boston, No. 2 . . .	2–11	20	1	280	336,000	
Boston, No. 3 . . .	7–1	24½	2	450	656,400	
Boston, No. 4 . . .	23–10	28	2	500	840,000	
Boston, No. 6 . . .	8–3	23–	2	530	682,500	
Boston, No. 7 . . .	23–	23½	2	500	705,000	
Boston, No. 8 . . .	7–2	23¼	1	250	355,000	
Boston, No. 9 . . .	10–	6	2	590	210,400	
Boston, No. 10 . . .	22	22½	2	450	634,500	
Boston, No. 11 . . .	3–13	8	2	500	149,300	
Boston, No. 12 . . .	22–14–15	8	2	500	186,000	
Boston, No. 13 . . .	10–12	19	2	500	370,000	
Boston, No. 14 . . .	9	8	2	500	135,000	
Boston, No. 15 . . .	23	23	2	510	688,200	
Boston, No. 16 . . .	24–11	4	1	250	58,200	Broke down.
Boston, No. 17 . . .	20	23	2	500	690,000	
Boston, No. 18 . . .	21–19	3½	1	240	46,800	Broke down.
Boston, No. 20 . . .	24	2½	1	250	37,500	
Boston, No. 21 . . .	24	5	1	220	66,000	
Boston, No. 22 . . .	8–	20 min.	2	500	10,000	Destroyed by falling walls.
Boston, No. 23 . . .	10–15	22	2	480	508,800	
Boston, No. 24 . . .	14–18	20	1	260	317,400	
Boston, No. 25 . . .	7–1	8¼	2	520	168,800	
Boston, No. 26 . . .	8	20 min.	. .	. .	. . . .	Destroyed by falling walls.
Boston, No. 27 . . .	3	11	2	420	229,200	
Boston, No. 28 . . .	6–5	6	2	470	146,700	
Boston, No. 30 . . .	13	6½	1	200	78,000	
Boston, No. 32 . . .	6–16–15	24½	2	460	368,000	

[1] Numbers refer to figures on accompanying plan.

Steamer.	Location of Steamer.	Hours in Service.	Number of Streams Played.	Gallons per Minute.	Total Quantity Thrown on Fire, Gallons.	Remarks.
Boston, No. 33 . . .	22–15–14	22	2	480	475,200	
Boston, No. 34 . . .	19	4	1	270	64,800	
Boston, Old No. 4 . .	17–19	7	1	280	117,600	
Boston Mystic Relief,	22–19–15	12	2	520	351,000	
Boston Relief C. . .	4	15	2	430	387,000	
Brookline	13	5	1	210	63,000	
Chelsea, No. 1 . . .	2–10	8	2	.600	301,800	
Chelsea, No. 2 . . .	1	6	2	600	216,000	
Cambridge, No. 2 . .	14–15	$8\frac{3}{4}$	2	570	300,000	
Cambridge, No. 3 . .	12	$4\frac{1}{2}$	1	350	94,500	
Cambridge, No. 5 . .	20–4	7	2	460	133,800	
Gloucester	4	4	2	445	106,800	
Haverhill	11	10	1	250	150,000	
Lowell, No. 2	25–13	9	1	280	141,000	
Lowell, No. 4	4	$9\frac{3}{4}$	1	280	163,800	
Malden	12	$5\frac{1}{2}$	2	500	175,000	
Medford	17	3	1	260	46,800	
Nashua	11	9	1	300	162,000	
Newton, No. 1 . . .	18	5	1	210	63,000	
Newton, No. 2 . . .	16	$4\frac{1}{2}$	1	250	67,500	
Peabody	25	$4\frac{1}{2}$	1	275	74,250	
Reading	25	4	1	240	57,600	
Salem	9	5	2	500	150,000	
Somerville	4–13	7	1	310	130,200	
Taunton	18	5	1	280	84,000	
Waltham	9	$2\frac{1}{4}$	1	325	43,875	
Woburn	4	4	2	450	87,300	
Worcester	19	3	1	260	46,800	
R. H. White & Co. .	. . . . .	4	3	700	168,000	
Hovey & Co.	. . . . .	2	2	440	52,800	

Mr. Jones.—I would like to say a word suggested by what the President has said with regard to the fire of 1872. At that time we had a great number of brick reservoirs which were supplied from our mains, and I found, the next morning, eighteen of them with 4-inch pipes from our mains leading into them, running at full head, running from the drain outlet within four feet of the ground, and those must have taken from the 12-inch and 6-inch pipes a large amount of water.

Mr. Darling. — I want to say one word. I didn't have any fire at my place, but I had occasion to test the hydrant service there last September on a line of 4,040 feet of 20-inch main, what we call the force main, running from the pumps to the reservoir; and we played 70 fire streams and maintained 80 pounds pressure. The standing pressure was 110 pounds, and when the 70 fire streams were playing, we had 80 pounds pressure during the time we played, — eight minutes. I merely made the experiment to see what service we could get out of the hydrants there. We played from nine 6-way hydrants and eight 2-way, making 70 fire streams.

The President. — I will now call upon Mr. Tidd.

Mr. Tidd. — I believe you did threaten to do that at the last meeting, or you asked me then to prepare a paper. I told you I should have no time to write anything, but after listening to the very able paper of Mr. Freeman, on fire streams, it occurred to me that there was a duty which we had, who were interested in water works in connection with the fire department, to have some understanding with that department as to the amount of water they could draw from any one particular portion of the service, in case of fire. Now, I suppose there are no works built, and probably never will be, so large that a certain number of streams might not reduce the pressure to such an extent as to destroy the efficiency of the streams. Of course it could be arranged easy enough between the fire department and the water department, so that they should understand that in certain quarters and from certain pipes, only a certain number of efficient streams could be drawn. If you draw one too many, or two too many, you reduce the pressure to such an extent as to render all the streams practically useless. It seems to me that it might be easily computed, or if that cannot be done, on account of various connections, curves, corners, and so forth, it might be easily ascertained by experiment. In the case of Lynn, for example, I understand the normal pressure there, which was somewhere about sixty pounds, was reduced to something like thirty at the time of the fire, — to twenty-three I am now informed, — even worse than I had understood. Now, it is possible that if they had reduced the number of streams they were using it might have rendered the others more efficient, so that the streams that were left might have been more valuable and made more impression upon the fire than the whole number which they did use. I don't mean to say that that is the case, but it possibly might have been. It seems to me that is a direction in which we ought to spend some talent and some attention. It is a thing easy to be done, and I regard it as very important. I have known instances — one case I have particularly in view, on a very small pipe, a 4-inch pipe — which ought to be legislated against. We have them in some towns, and in large numbers; however, this was on a 4-inch pipe of considerable length, where a house took fire and burned down between two engines, either one of which would have saved the building if the two sets of firemen hadn't insisted

upon playing upon it at the same time. (Laughter.) A 4-inch pipe, under the pressure they had, would have been just enough to have carried one stream to the house, and one stream would have saved it; but neither company of firemen would let go, and between the two the house burned. (Laughter.) I merely mention that to illustrate the point I wish to make. It seems to me this is a thing of importance, and I would like to hear a discussion upon it by some of the members.

Mr. Jones. — I merely want to ask a question in regard to one thing. Mr. Freeman spoke about a 4-inch pipe for fire purposes, and he made the remark that the man who laid such a pipe as that ought to be hung.

Mr. Tidd. — I agree with him perfectly. (Laughter.)

Mr. Jones. — Now, as I have put in a great many of them, and as our President has also, I should like to know how many more candidates for the gallows there are here. (Laughter.)

The President. — I think Mr. Freeman's meaning, in that statement, was a line of pipe surrounding a mill, — a long line of pipe of that size, and not a short pipe from the main into the mill.

Mr. Jones. — I am glad you so understood it, for I supposed I should be hung before a great while. (Laughter.)

Mr. Tidd. — In my reference to a 4-inch pipe I did allude to a long line in a street. I consider that four feet of 4-inch pipe is a ridiculous length; but this was something over 1,000, perhaps 1,500 feet, the one I alluded to particularly. I wish there was some law which would prevent the use of 4-inch pipe for any length as a street main.

The President. — Mr. Kimball, of Somerville, I think, promised to give us something.

STEALING WATER.

BY

Geo. A. Kimball. Jan. 8, 1890.

Mr. Kimball. — I did not promise, but you insisted I should say something. What little I have to say I have not had the opportunity to put in writing, and therefore you will bear with me if I make a few rambling remarks. The matter I propose to mention is something I investigated several years ago. I think, perhaps, it would be best not to mention the name of the place or the names of the parties connected with it. The subject is "Stealing Water." (Laughter.) It occurred in a city not more than twenty miles from Boston; it was not more than twenty years ago, and the parties connected with it are nearly all dead. There came into the office of the superintendent of the water works, one day, a man somewhat under the influence of liquor, and he asked the superintendent what the fine was for stealing water; and went on and made certain statements by which it appeared that the manufacturing establishment with which he had been connected for a great many years had discharged him for dissipation, and he came to tell the superintendent that this establishment had been stealing water for ten years, by a very systematic arrangement. Investigation showed that from the street main there was carried into the yard a four-inch pipe, and about sixty feet from the line of the street, in the yard, was a meter. The pipe continued beyond the meter to the other end of the yard, and then ran off at

right angles to a well. From that well a pipe was carried back to a point nearly opposite the meter, and about sixty feet distant. This well had a pipe connected that was arranged with a pump, and the water for the establishment was supposed to be pumped from that well.

At some time, and in the night, a connection was made from the end of the pipe to a point between the meter and the street, and the water was taken from the pipe from the water-main and carried around the meter, as we might say, into the well. To go upon the premises and examine, you would see that the water was pumped from the well, and would suppose that all the water used by this manufacturing establishment had gone through the meter, when really the well had proved insufficient, and the proprietor of the establishment had taken this means to replenish it. A large amount of water was allowed to pass through the meter each quarter, so the inspector might not discover that anything was wrong, and the bills at that time amounted to about $1,200 a year.

When this was discovered, — I might say it was discovered soon after the death of the proprietor of the establishment, and was readily acknowledged by those then in charge that such a thing had been going on for a good many years, — when this was discovered and the fraudulent pipe cut off, the rates increased to $3,600 a year, making a difference of $2,400. This fraud had been going on for ten years, making a total amount of $24,000. Further investigation of the affair showed that at a prior time this establishment had been connected with the water works of another city, — it was located near the borders of another city, and this other city had found that they had been stealing water, and imposed a fine upon them of $500, which they had readily paid. This was ten years previous to the discovery of the matter I am referring to. They had readily paid the fine of $500, and said they didn't want any more water from that city, and then made this little arrangement, which I have described, and during the ten years had succeeded in stealing water to the amount of about $24,000, and perhaps more, — nobody knows how much. I think, gentlemen, superintendents, you can possibly gain something from this experience. The moral is, always keep your meters in the streets. (Applause.)

The President. — I suppose the people in other parts of the State are honest and never do this sort of a thing, but I am going to ask Mr. Hawes, of Fall River, if he ever heard of any such case in Fall River.

Mr. Hawes. — Not on so large a scale as that, but we did find one case there. (Laughter.) There was a tremendous leak in our water one day; the water went down at the works, and they telephoned to the office and wanted to know what was the matter. No one at the office knew what the matter was; they knew there was no extra draught on the pipes; but our superintendent, Mr. Kieran, had a pretty good idea where the trouble was, as the water in the ponds was very low, and it was almost impossible at some mills to get a supply for condensing water for the engines. The main went down two streets, and then there was a street right across where the pipe went, and nothing to connect with it up in this cross street except a certain mill. So our superintendent goes up and shuts off the water in that street, and pretty soon the superintendent of the mill comes out and says, "What is the matter here?" — "I've lost a nut," Mr. Kieran said, "and we can't find it." — "Come right in the machine-shop and get one." (Laughter.) — "Oh, no hurry." — "Suppose our mill should get a-fire?"

—"We have a man at each end to let the water on if there should be an alarm." Very soon he came out again and said, "Come into the shop and we will give you a brass nut." I guess he would have given a gold one or a silver one. (Laughter.) Mr. Kieran says, "I guess we will find it before a great while." He had one in his pocket all the time. (Laughter.) Pretty soon the mill shut down and the boys came out. "What's the matter, boys?"—"Can't get any water to run the engine." (Laughter.) Pretty soon the superintendent came out and asked him how long before he was going to let the water on. "In the course of an hour." —"Well, but," he says, "we want it."—"What do you want it for?"—"Well, but we can't run."—"But you are not getting your supply for your boilers from this?"—"No."—"Nor you are not condensing with it?"—"No."—"Well, what do you want?"—"Well, we want the water on." (Laughter.) The mill didn't start up till the water was let on, and then we found he was drawing water from an 8-inch pipe into his condensers. And we investigated and found that that pipe had been connected, so that they had used at least $3,000 of water, as near as we could estimate. It was put on with the knowledge of the superintendent, and the treasurer ordered it on, but, like Mr. Kimball's man, he had died. (Laughter.) It was generally considered he wanted more water after he died than he did when he was alive. (Laughter.) However, we investigated, and the engineer came before us and testified that he didn't use water for condensing purposes. He was asked if the water sometimes got low in his trench. "Yes, quite often."—"Well, how do you run?"—Well, he ran without any condensing water.—"How do you run your condensing engine without any condensing water?"—Oh, he could run it a considerable time.—"Well, how long?"—Well, he didn't know.—"Two hours?"—"Yes."—"Five hours?"—"Yes." Finally he went so far as to say he could run it three-quarters of a day without any condensing water in his condenser. Well, that was a new theory,—something new to us. However, the new treasurer came forward, and he said he had no doubt the water had been stolen, and whatever we thought was right they were willing to pay; and we sent in a bill, and he paid us, I think, some thousand dollars. I think that is what we estimated had been used while he had been in charge.

The officers of a corporation seem to feel very often that they have a right to steal from the city. If a boy stole a handful of cotton from them, they would have him arrested and sent over to the New Bedford jail; but they think they have a perfect right to steal a thousand dollars' worth of water from the city. It got so serious with us that we found we had got to do something desperate. We would find, every once in awhile, a mill had put in a new set of water-closets and connected them with the fire-pipe; or had put in this and that, and made connections with the pipe; and we finally employed an inspector to go around, and we sent notice to all the mills that they must put in meters. Well, their supply pipes were from ten to twelve inches, and the meters were going to cost from $800 to $1,000 apiece, and the mill folks got frightened. So finally we made them have a pipe entirely separate from the one for fire purposes,—for supplying water for drinking, washing, and so forth,—and have it so we could look it all over any time we were a mind to and inspect it, and put a meter on that, and then let them use the other for fire purposes entirely, and nothing else. But once in a while we will find that they have tapped the fire-supply pipe; and then the superintendent will say he don't know anything about it, that it was the bull-

headed plumber who did it (laughter), and they think it is rather hard when we require them to take it out and plug up the hole. We have to watch them all the time, and even then some of them will hook on. If you get pay for all the water you are very lucky.

Mr. Jones. — I should like to ask the gentleman who introduced this subject, if the intoxicated man had been stealing water?

Mr. Kimball. — I can't say, Mr. Jones, as to that. There is one other little fact I neglected to mention. During these ten years, one year the proprietor of the establishment allowed an unusual amount of water to pass through the meter, so that their bill was quite a little more than $1,200, perhaps several hundred dollars more, and when he received his bill he came up to the water office and said that something was wrong, that he hadn't used as much water as that, though all the time he was stealing it at such a wholesale rate; he said he hadn't used as much water as that, and he wouldn't pay the bill. The bill was referred to a committee for investigation. The chairman of the committee was a very smart, bright man, and they went up to the factory and spent quite a long time, several hours, examining to see what the difficulty was. They went to the well and examined the pipe and the gates, and so forth, and reported back that some mistake had been made, and that there should be an abatement of the bill, and so it was reduced to the usual amount.

The President. — I will now call upon Mr. Fuller.

THE LAYING OF A TEN-INCH PIPE IN LEICESTER, MASS.

BY

F. L. Fuller. Read Jan. 8, 1890.

Mr. Fuller. — I thought, perhaps, I might interest the members by telling them a little about a supply that is being put in for the town of Leicester. It is a gravity supply, and is obtained in the adjoining town of Paxton, which is about 5 miles distant in a straight line, and somewhat longer by the pipe line. Where this supply is obtained is a sort of a level plateau, and the pipe line is nearly level for a long distance; in fact, in about 10,000 feet we are only able to get a fall of about 10 feet in a 10-inch pipe. It is being laid about the line of grade, and the upper end of this pipe, which is practically a siphon pipe, will be about 7 feet below the water in the large well, which is to be built at quite a large spring which is to furnish the supply. The pipe is laid through about 3,000 or 3,500 feet on the bottom of a pond. The pond has been drained down, and this pipe has been laid in the bottom of the pond, with a cover varying from 2 feet to 6 feet, and in some places it has been necessary to use piles. We have used piles 16 feet in length, the longest of them, and running down to 3 or 4. The short piles have been driven with a beetle, and the longer ones have been driven by using a weight weighing about 400 pounds, which has been attached to the block and fall of the derrick which is used for laying the pipe. There has been no particular trouble in getting these piles down, and after they have been driven down to the solid bearing they have been cut off level, and a cap 5 inches square placed across the piles, which were about 22 feet on centres, and this cap secured to the piles by putting a pin, an oak trunnel, through. Being laid below the pond, and when above the pond, in ground that is comparatively wet

most of the time, this pipe will be under the ground water, and probably there will be no serious trouble in using it as a siphon. The pipe is to be tested so as to make sure it is tight; and I might add, as to the weight of the pipe, it is a 10-inch pipe, and it weighs 50 pounds to the foot, which is pretty light. There has been some trouble from breakage in cartage, as has been referred to before.

The deepest cut will be about 20 feet for a short distance, and 15 feet for quite a number of hundred feet. I had only two bids for doing the work. One man bid $1 a foot for laying, and the other bid was 23 cents a foot; so you can see there was considerable difference. This pipe runs down through a stream at the head of what is called Arnold's Pond, and in the 2,000 feet below this is this deep cut, which I have spoken about, of 20 feet, and then the pipe pitches down quite steeply, quite sharply, to the village of Cherry Valley, which is just above Worcester, where there will be a head of about 400 feet. Then the pipe runs up into the village of Leicester, where there will be about 100 feet head; and it is proposed to locate a stand-pipe on the hill just to the north of the village, where the ground is about 40 feet lower than the surface of the water in the spring, and here a distributing reservoir will be built, of 30 or 40 feet in diameter, and about 40 feet high. I don't know as there is anything quite like it in this vicinity, and I didn't know but what it would interest some of you who are here.

Mr. Stacey. — I would like to inquire, if it is not asking too much, whether the dollar or the twenty-three-cent man got the job. (Laughter.)

Mr. Fuller. — I will answer Mr. Stacey by saying that the contract was given to the lowest bidder, and he is doing a pretty good job, and I think will finish the work satisfactorily, although he won't make much money.

Mr. Winslow. — I would like to ask Mr. Fuller what depth he is laying the pipe, and what he does, — whether he furnishes the labor, or the labor and lead, for that price?

Mr. Fuller. — The cover in the pond, in a few places, is perhaps not more than a foot or two, and it increases, so that in some places there is a little over six feet cover. As to the work the contractor is doing, he is furnishing the lead and everything that usually goes with pipe-laying. At the prices he gets for piles, and the timber foundation which we have to use in some places, probably there is some little profit for him, which helps him out on the 23 cents per foot for the pipe-laying. If I remember rightly, — I haven't the figures with me, — he gets 12½ cents a foot for the piles driven, which are supposed to be 5 inches at the small end and 6 inches at the large end, and at the rate of $75 a thousand for the caps in place. Of course that don't amount to a great deal, so he can't make very much on these items.

The President. — I think Mr. Winslow, of Waltham, agreed to say something this afternoon.

EFFECT OF WATER-HAMMER ON CEMENT-LINED PIPE.

BY

Geo. E. Winslow, Waltham, Mass. Read Jan. 8, 1890.

Mr. Winslow. — What I have to say is not really in the line of what has been spoken of here, although a good deal has been said about the effect of

water-ram on pipes, and it may be pertinent in that connection. We have in our town a good deal of cement pipe, something over half of our pipe, and in times gone by breaks were very frequent. In fact, when the works were first put in they would very seldom have a fire, or even test the hydrant, without bursting a pipe or, perhaps, pipes. It got so bad there at one time that there was one man who was connected with the water works, — that is, when it was done under the old town form the work was done by contract, — who was made responsible to go to the hydrants and open them for the fire department, and close them for the fire department, to see if this bursting of the pipes could not be prevented. Of course that didn't work. At the time I took the works, which was eight years ago, we had leaks there, a great many of them, although the bursts from operating the hydrants were few. I would say that, up to that time, the firemen in testing the hydrants, if they found they went hard or were in any way out of order, would take off the cap and try to remedy the difficulty themselves. The style of hydrants which was in use at that time was the old style of Boston hydrant. They would take off the cap and oil the spindle and nut, and so forth, and put it back; and the consequence would be they would leave them, perhaps, a little loose, and when they shut the valve by the centre of the pressure of the flow, it would bring the valve down to its seat with a sudden motion, and produce quite a water-hammer. After I took the work I objected to their doing anything of the kind. I told them, if the hydrants were out of order I preferred to know it and to fix them myself, and after a good deal of work I made out to get it arranged in that way.

Well, since I commenced to take care of them myself, I have looked out for this very trouble; that is, looked out for any end-shake or back-lash in the valve-rod. I found in all leaks that the pipes were rusted badly, and the cement in a good many places was cracked, which allowed the circulation of air or water to come in contact with the shell of the pipe. I found, also, in taking out pipes, that the cement in all cases was wet through to the pipe, and the pipe would be wet; but I made up my mind that the circulation of water was so slight that it could not rust it, or, in other words, it wanted circulation of the water or air on the iron in order to rust it, and as soon as that happened it would weaken it, so that any heavy, or even slight, water-hammer, of course, would burst it. When I found that was the trouble, of course I knew there was a lot of it which would show in time to come, and I wanted to stop any further trouble of that kind. So I put a man on to all of the old Boston hydrants, and chipped off the top so as to bring the cap down closer; and I have found that, with a very few exceptions, I could take up from a sixteenth to an inch end-shake. Now, a sixteenth or an eighth of an inch movement of that valve, when it got to the right point, shut off a large supply of water, which, moving at the velocity that it did, made a very heavy water-hammer, and I have found main pipes broken by the shutting of that at quite a distance from the hydrant, — perhaps 1,200 feet. Since I have had those hydrants fixed I have found that my leaks have decreased very rapidly. Before that was done, the leaks would run up to 25 or 35 or 40 a year. They have decreased now; so this last year we have had, I think, four leaks on my cement pipe, which you might say could be traced to the action of water-hammer in times past. Last year the leaks were very few. I don't say that the trouble is all ended, because I think the damage has been done, the pipes have

been weakened, the cement cracked, and the pipes are rusting and will come out; but I do think that if that water-hammer had been stopped in the first place our cement pipes would be in a great deal better condition to-day than they are.

I have heard some of the members speak about using elevators. I have but one elevator in Waltham connected with our mains, and that is from a cement pipe. It is connected with a 2-inch pipe; it was put in by a Worcester firm, and they showed me the valve they were going to use, and I told them I should require a relief valve on the service pipe close to the valve the elevator was worked with. The man in charge of it wanted to know why, and I told him because they could shut the valve so quick that they could create a water-hammer that would burst our main. He thought it was foolish; but I said, "Our pipes are cement-lined pipes, the iron is thin, and it hasn't got the strength of cast-iron pipe; if it had, perhaps it would not be necessary to take this precaution." Well, they finally put it on, and we have had no trouble from it, for there is no water-hammer; if there is pressure enough so that we might get a water-hammer, the water escapes through the relief valve.

We also have a stand-pipe in Waltham for the Fitchburg Railroad, and Mr. Turner, the chief engineer of the road, wanted to connect with our mains and put on a slow-moving gate; that is, a gate with a fine thread, so they would shut the valve slowly, so they couldn't produce any water-hammer. He wanted to get rid of a tank which was an eyesore in front of the depot. I told him I was afraid, that with the men who generally work valves on a railroad, they would burst our pipe by increasing the pressure rapidly by a sudden closing of the valve. He said they wouldn't do it, and he said, furthermore, "I will put on a good, careful man, and he will be responsible." But I saw one of those careful men operate a valve in Worcester at the Union depot, one day, when I was up there to see what kind of an arrangement they had, — to see what I could do for the Fitchburg Railroad. The express train came through there along about twenty minutes past three in the afternoon, and I knew they would water-up, and so I went to the depot to see them do it. The water was turned on, and the fireman didn't pay attention to his business as closely as he ought, and the consequence was, the tank got pretty near full before he noticed it. "Shut it down, you will overflow in a minute; hurry up, hurry up!" And they did hurry up, and that valve was shut just about as quick as it could be shut. That was the careful man who was taking care of that valve. Now, I made up my mind that would be the case in Waltham, so I told Mr. Turner that if he would put on a relief valve which would be large enough I should be happy to put in a service for him. He didn't like that idea; and he is a pretty set man any way, as well as myself, and the consequence was, we went through that fall and winter without any stand-pipe. In the spring he came to me, one day, and he asked me when I was going to put in the service for him. Said I. "Just as soon as you can conclude to put in a relief valve. As I understand it, you want a 6-inch pipe taken off from the street main, run through a 4-inch meter, and then a 4-inch pipe to your stand-pipe?" "Yes." Said I, "As soon as you will put that in, and put in a relief valve close to the valve which operates the stand-pipe, and that shall be a 3-inch valve, and not be set at over ten pounds above the standing pressure, just so soon we will put it in for you." Said he, "I will put in anything you want." And the consequence was he put it in, and we

never have had any trouble, as yet; the pipe has been all right, the meter has been all right, and everything has been all right. My idea in regard to keeping pipes from bursting is to avoid water-hammer as far as possible, especially with cement pipe.

Mr. Jones. — As the gentleman has spoken about cement pipes, I would like to make one suggestion with regard to that subject. At the last meeting, I think it was, Mr. Nevons and Mr. Richards were talking about cement pipes, and Mr. Nevons made the remark that he had some number of miles of cement pipe he would like to sell, and that he would throw in the cost of laying the pipes if he could sell them. As this is the only time I have heard anything said about cement pipes, and as I have been asked a great many times during my experience in the water works, and since then, what I thought of cement pipes, and never having had any experience with them, I could not tell, I should be glad to hear something more about them. I suppose there are associate members here who lay cement pipes, and who can say something on the other side of the question. When I say the other side of the question, I mean my side is very unfavorable to them, so much so I would be glad not only to throw in the laying, but, if that wasn't enough, I would throw in my situation as superintendent. (Laughter.)

Mr. Barrett. — If I was able to, I should like to enter into a discussion on the merits of cement-lined pipes. At some other meeting I shall be willing to try to hold my end up. Our superintendent will back me up, and we can tell you why we believe in it in Woburn.

Mr. Nevons. — I am very much surprised that any member of this Association should want to open the cement-pipe question here again. (Laughter.) I was called on to say something about it once, some ways from home, and I said there that this Association had discussed the matter, and had decided that cement-lined pipe was the best pipe to use, if it was only made right. There seemed to be a good deal of surprise manifested when I made that statement, and so I went on to say, that in order to have it made right you wanted to have the iron somewhere from three-quarters of an inch to an inch thick, and then you could put the cement on just as you were a mind to. (Laughter.)

Mr. Allis. — The gentleman who read the paper spoke of the breaking of the pipe caused by the operation of the hydrants. I should judge, from what he said, he thought the water-ram was what caused the breaking, and I should like to ask if that is what he meant, — that that was the only trouble? It would seem to me hardly in accordance with the experience of myself and others, who have a large lot of cement pipe which we wish we hadn't got.

Mr. Winslow. — I wouldn't say it was the whole cause of our bursts — yes, I will say of the bursts, but not of the leaks in our cement pipes. I know of one line that was built by contract eight years ago this last summer, and when they turned the water into it it leaked considerably. The water that leaked out of that laid along in between the outer covering, and perhaps the inner covering, so far as that goes, and the cement, and would rust the iron so that in time it would weaken it. But in cases of bursts, I think they were occasioned principally by the shutting of the hydrants, or some outlet where there was a large flow, suddenly, and creating a water-hammer.

Mr. Allis. — I have had a good many breaks in a year, having about 54 miles

of this pipe, and I have had experience of this kind: we will dig down and find the water running out of a gap two or three feet long, and the iron as thin as a piece of paper, and thinner, too, and the rust all around the whole length of the pipe. It appeared to me that the pipe had been rusting for a good many years, and it finally reached the very last breaking-point, and away it went. In nine cases out of ten, in my own experience, the breaks have been of that character, where the pipe had deteriorated till there was nothing left of it. Of course, we all know that that might be owing in many cases to poorly laid pipe, and I heard after I took charge of our water works that the contractor sometimes, when he was in a hurry, would stick the pipe into the ground without waiting for the cement to dry, and of course we couldn't expect such a pipe to last many years. I think there is a chance for good cement-lined pipe to last quite awhile; nevertheless, at the present price of cast-iron I would not advocate laying any cement pipe.

Mr. Winslow. — There are a great many of us who have cement pipe in our systems of water works, and we have got to take care of it as best we can, because we haven't got the money to replace it with cast-iron at present.

The President. — There is one question which has been brought up in discussing the size of pipes, and that is the question of fire pipes, which I wish to have carefully considered, because I think it is one which will be of great importance to all of us, and especially to those in the larger cities, where the use of fire pipes is more general than it is in smaller places. In Boston we have a very large number of these pipes now, and since the November fire I have had a dozen applications for 4-inch pipes. The other day an application was made for four 4-inch pipes in one building. The question to be considered is, whether the introduction of these pipes, which is practically demanded by the fire-insurance companies, will not have the effect of impairing the efficiency of the water-supply in case of large fires; in other words, whether it will not have the effect of defeating the object which is had in view. There is no question but that the fire pipes in buildings which are destroyed by fire will be broken off and the water will escape into the buildings. It is a practical impossibility to shut off the water in the case of a large conflagration after the walls have fallen, and a large number of these pipes will be sufficient to cripple any system, I don't care how large it is; that is, any system which is in use to-day. It is my opinion that the water for fire supply should be kept underground, and where it will be protected as far as possible from any danger. I think Mr. Haskell, of Lynn, from what he has told me to-day, has some opinions on this point, and I don't know but other gentlemen may have. I think it is a question which is bound to arise between the water companies and the insurance companies, and it is a question that must be discussed and settled. If Mr. Haskell has anything to say, we would like to hear from him.

Mr. Haskell. — I was not intending, Mr. President, to say anything whatever on the subject to-day, but I will say this, that at the commencement of our fire, knowing there was going to be a large fire, I started out four men to shut off all the large pipes that we could shut off. We had quite a good many 4-inch elevator pipes, and a good many 2-inch and $1\frac{1}{2}$-inch pipes, and we shut all of them off. The fire-sprinklers I didn't dare have shut off, for the reason I was afraid it might complicate the insurance. A man having a fire-sprinkler in his

building, and it being tampered with, I didn't know but the city might be called upon to pay some of the insurance, and for that reason I didn't have any of them shut off.

We had one elevator pipe broken off entirely by the fall of the building, a 4-inch pipe, and till ten o'clock the next morning the water was allowed to run out of that pipe freely. There was one fire-sprinkler we were not able to close after the building had fallen, for there was about six feet of brick on the shut-off. In all cases where we put in 4-inch sprinklers we put the shut-off as close to the main pipe as we can, and we shut off all of those with one exception, and, as I say, there was six feet of brick on top of that and we couldn't get at it. One man was quite severely burned in trying to shut off one of these sprinkler pipes after the building had got so thoroughly on fire that there was no danger of the insurance question coming up. We only had two large pipes to draw on for our water-supply, and we did suffer from a great loss of water.

Now, as to the question of the future demand upon water-supplies, I will state the position that the city of Lynn is in to-day. On 70 feet of one street we have got five applications for 4-inch sprinklers to be put on an 8-inch pipe. Now, if there should be, as I think there will be, three applications on the other side of the street, — I am discouraging them as much as I can, — there would be in 70 feet, on a street which is only 50 feet wide and supplied with an 8-inch pipe, eight 4-inch sprinklers demanded.

A STUDY OF ALGÆ GROWTH IN RESERVOIRS AND PONDS.

Read before the Association, February 12, 1890.

BY

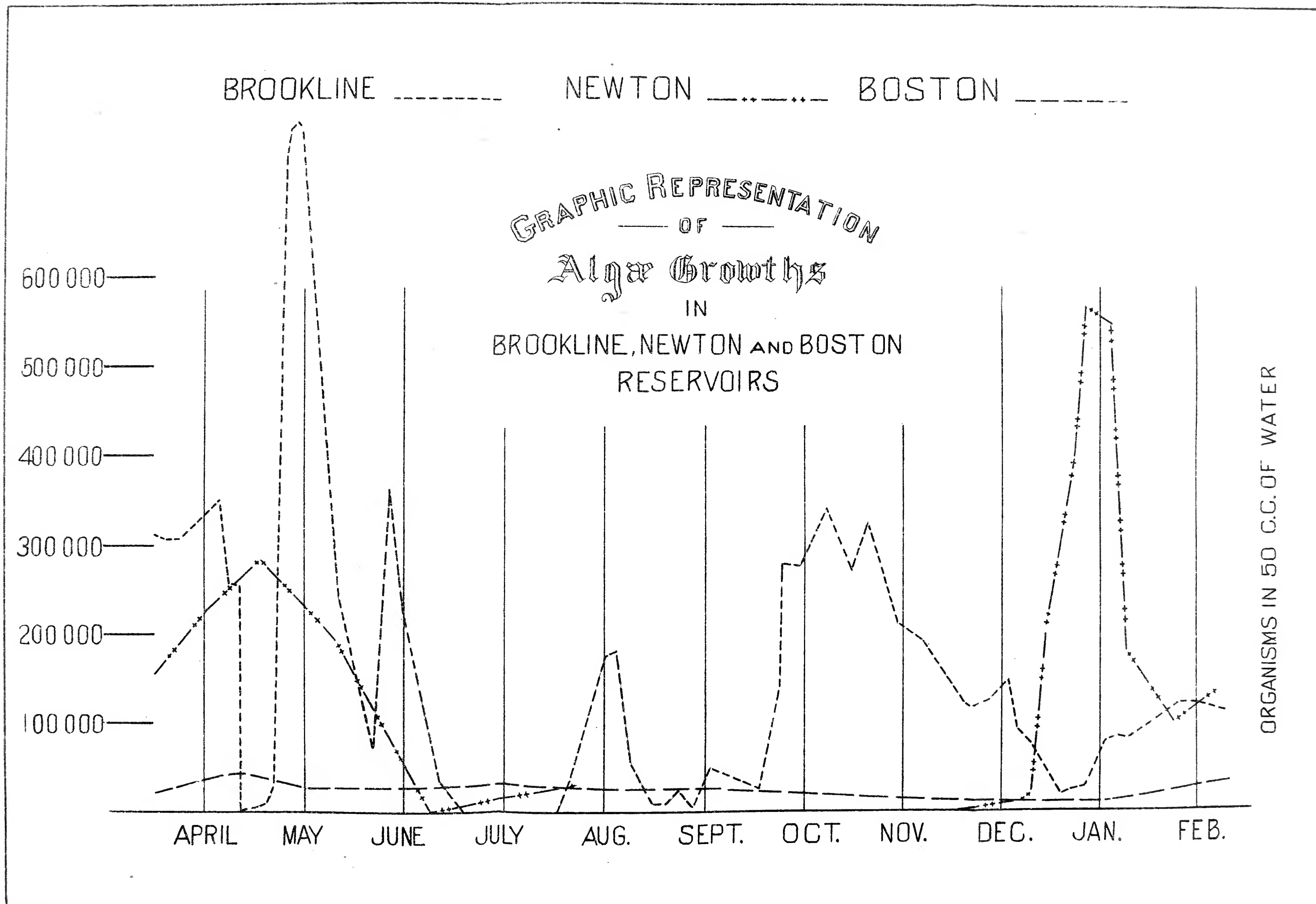
F. F. Forbes, Supt. of Water Works, Brookline, Mass.

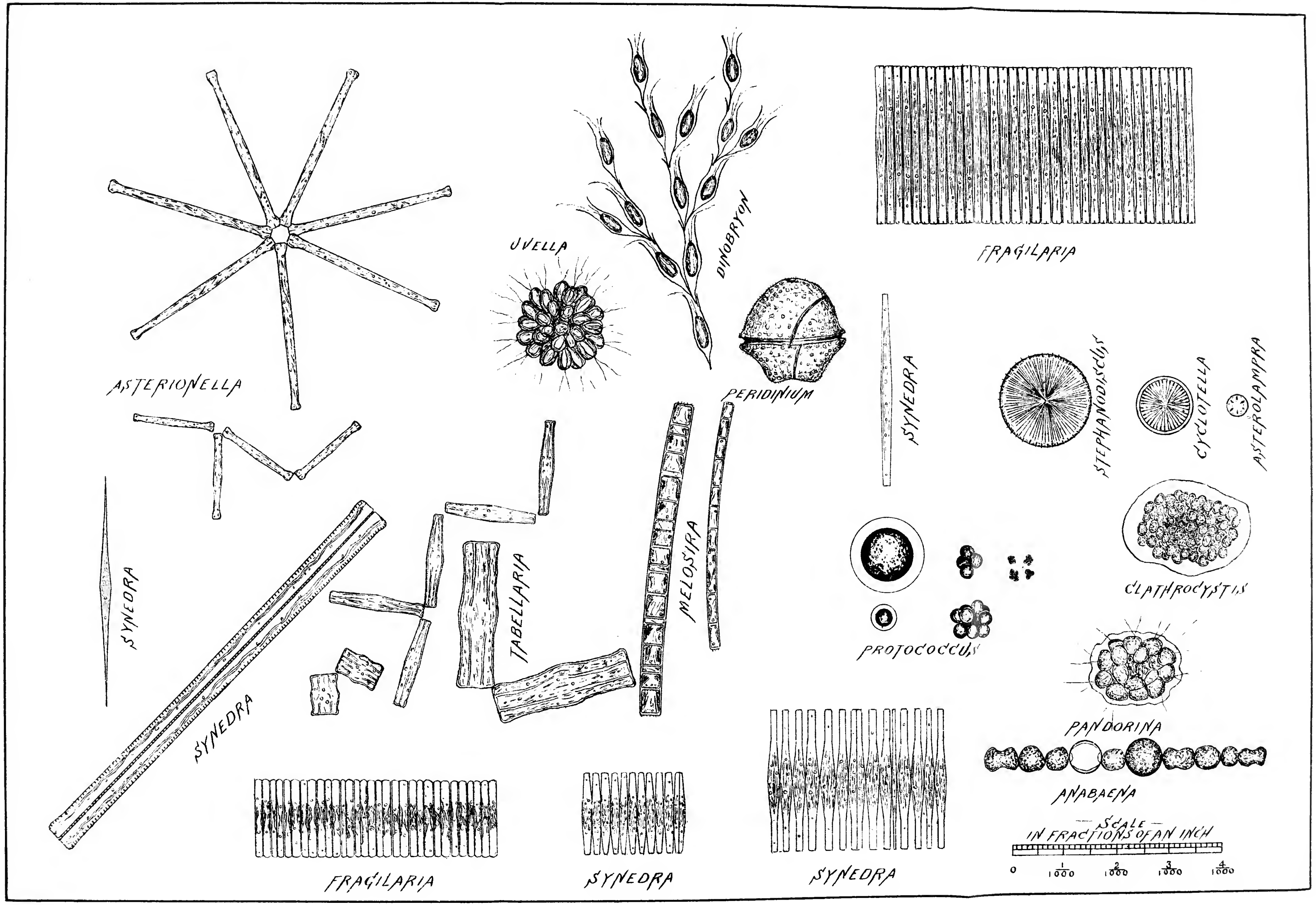
Probably there are few superintendents of water works in this country, or in fact in any other, where the water is stored or drawn from basins or reservoirs exposed to sunlight, who have not had more or less trouble from minute water-plants, called algæ, which often find in these basins and reservoirs an excellent place for their growth.

In some waters the conditions are so favorable for their development, that by their rapid growth and as rapid decay the water is made exceedingly disagreeable to the taste and smell, and the whole system is a failure as far as delivering to the consumer a pleasant and wholesome water, which is the chief end in view.

At first thought, it seems hardly possible that such minute organisms as these plants can do so much mischief, and it appears to me that any facts which may be learned from a study of these organisms cannot fail to be of interest, not only to those closely connected with the management of water works, but also to the consumer, who is obliged to take such water as flows from his faucet.

This afternoon I will invite your attention to a brief account of the few inves-


BROOKLINE
NEWTON
BOSTON
GRAPHIC REPRESENTATION OF Algæ Growths IN BROOKLINE, NEWTON AND BOSTON RESERVOIRS
600 000
500 000
400 000
300 000
200 000
100 000
APRIL
MAY
JUNE
JULY
AUG.
SEPT.
OCT.
NOV.
DEC.
JAN.
FEB.
ORGANISMS IN 50 C.C. OF WATER



ASTERIONELLA
UVELLA
DINOBRYON
FRAGILARIA
PERIDINIUM
SYNEDRA
STEPHANODISCUS
CYCLOTELLA
ASTEROLAMPRA
SYNEDRA
TABELLARIA
MELOSIRA
CLATHROCYSTIS
PROTOCOCCUS
SYNEDRA
PANDORINA
ANABAENA
SCALE
IN FRACTIONS OF AN INCH
0
1/1000
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FRAGILARIA
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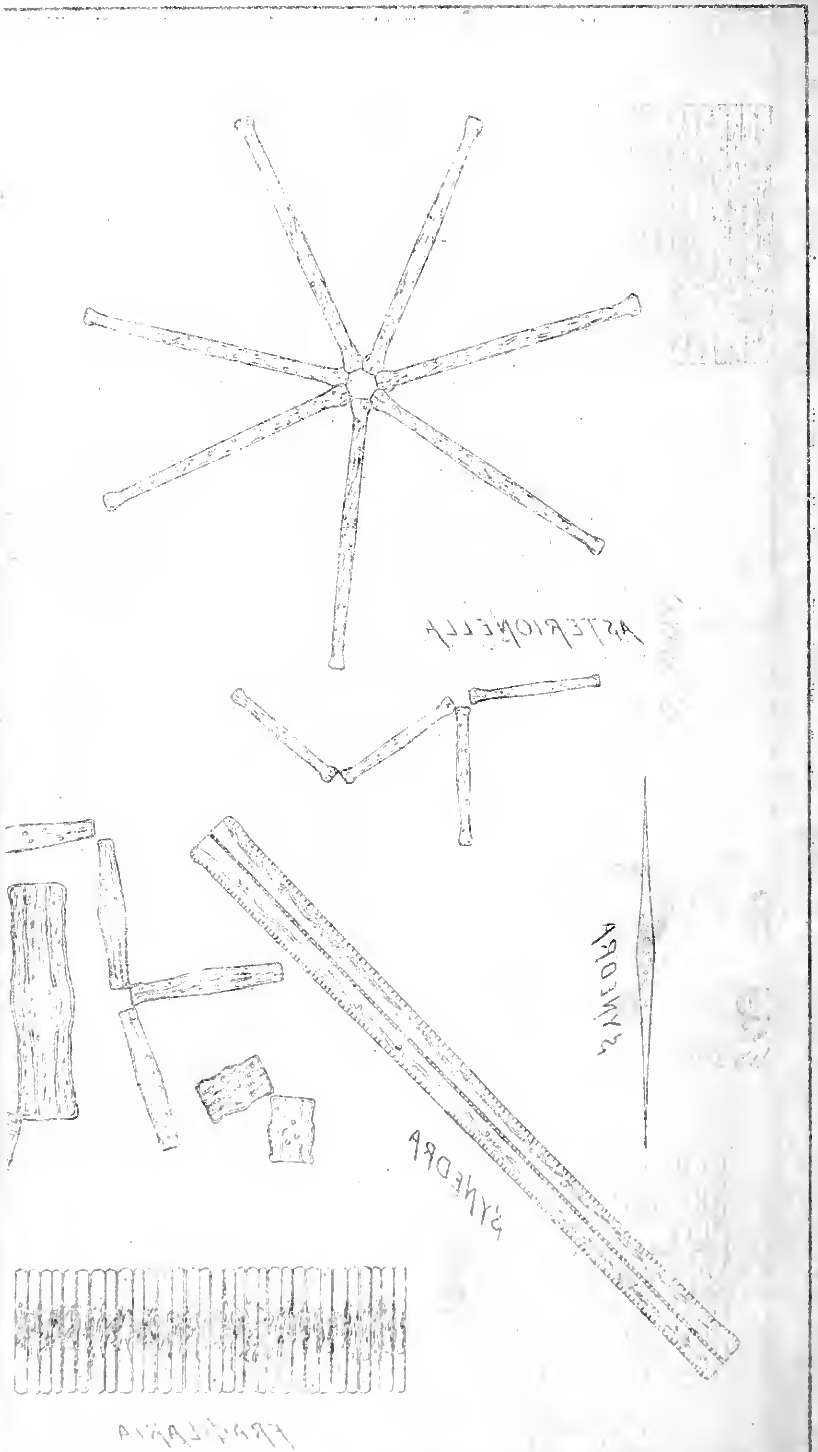
ASTERIONELLA
SYNEDRA
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FRAGILARIA

tigations which I have made in this direction, and also to information which I have obtained from the labor of others.

It has often been remarked, that as cold weather approaches, the algæ which have flourished during the summer would disappear, and reasoning from the habits of plants which are visible to the naked eye, such a remark would be correct. In early spring we see the trailing arbutus, the violet and dandelion, later these give way to the daisy and chiccory, and still later, the gentian and golden-rod dot the meadows and hillsides; and then the autumn frosts turn the forest leaves, kill the flowers, and leave the fields brown, soon to be covered with the winter's snow. So accustomed are we to these changes, which the seasons bring to the visible vegetable world, that we should be very much surprised to see, on some cold winter's morning, the forest trees in full leaf, and the summer flowers show their faces through the frozen ground; yet nearly all kinds of algæ flourish as well in winter, even under the ice, as in the warmer days of July and August.

Furthermore, we all know that the trees put forth their leaves only in the spring, and the golden-rod blossoms only in the fall; but a certain algæ formation may appear in one body of water in July, this year, and perhaps in any other months the following year, or not at all, while in a neighboring body of water the same plant may devolop in just the reverse order.

During last winter melosira was quite abundant in the Boston reservoirs, but as spring came on it disappeared almost entirely, and from a study of this diatom in this body of water alone one might conclude that warm weather was unfavorable to its growth; but a sample from Pawtucket reservoir, taken Oct. 3, 1889, showed this diatom in very large numbers and in a healthy condition, so we must conclude that the change in temperature alone, only as far as it affected its food-supply, or made it more favorable for some other plants, had little or nothing to do with its disappearance.

To further illustrate how little influence change of temperature has upon algæ growths, I will now call your attention to the results of microscopic examinations of water from Brookline reservoir of Brookline Water Works, from the Boston reservoirs in Boston and Brookline, and from the Newton reservoir of Newton Water Works; and, for convenience of this paper, commencing about March 15, 1889, and continued to date. The examinations of the water from Brookline reservoir were made about every 5 days, from the Boston reservoir once each week, and from the Newton reservoir at much longer intervals, with few exceptions.

On this chart, which you see, the number of organisms found are shown graphically.

It will be observed that about April 10th a growth started in the Brookline reservoir which increased remarkably, and reached its maximum in about 20 days, then growing less, with the exception of a short time immediately after a quantity of fresh water had been pumped into the reservoir, until nearly all the algæ disappeared, and during the warm days of July the water was almost free from these plants, and without smell and taste.

As already stated, reasoning from the habits of plants which are seen on every hand, we might expect an abundant growth to commence in the spring, as it did in this case; but it should continue through the summer months, which we see it did not.

Now, in the Newton reservoir we find a similar growth, but starting about December 12, instead of in the balmy days of spring, increasing astonishingly, reaching its maximum in about 30 days, and then decreasing until the water contains little organic matter in a live state.

Here we see a growth in winter resembling in every way a growth in spring; and, as we examine this chart carefully, we must conclude that the temperature which prevails at different seasons has little influence upon the growth of these minute plants, only as far as it affects the food-supply.

The reason for the large growths in both these reservoirs will be fully explained further on.

The growth in the Boston reservoirs, however, would seem to indicate a somewhat different result, for we see, in June, that the number of organisms begins to increase and continue larger till the weather grows colder; but a careful study of these organisms shows that the warm weather alone is not directly the cause.

The increase in number is not in that class of plants which were present during autumn, winter, and spring, — these, in fact, are less, — but is wholly due to plants of an entirely different family, — the Nostoc, with habits much unlike those just mentioned.

The plants of the Nostoc family derive their food to a certain extent from the decay of organic matter, and are never found in ground waters similar to those of Newton and Brookline. They grow in summer, probably not only because the weather is warmer, but for the reason that, as the temperature of the water rises, the decay of the organic matter present is hastened, and certain chemical changes take place which furnish just the kind of food these plants require; and if this food could be supplied in mid-winter, I have little doubt that this family of plant would flourish then. And I might add here, for reasons just stated, that water which contains a large amount of organic matter, either in the form of mud on the bottom, or sewage matter, may support a large and troublesome growth in summer and very little in winter.

As is well known, the temperature at which different plants can form their protoplasmic food, or in which assimilation is possible, varies greatly. The red snow-plant, for instance, which often spreads over acres of snow in the Arctic regions, grows rapidly in a temperature at about the freezing-point of water. The same is true, as has been shown, with most of the common algæ. The cold weather may retard the time of maximum growth somewhat, but if in a body of water there is a certain amount of food material, the number of organisms will be about the same whether it is winter or summer, and any change which varies the food material changes the organic life to the same extent.

It is not a question of temperature, but food material.

Now, let us look again at the growth which commenced about December 12th in the Newton reservoir, and rose as greatly above its normal state, for the purpose of finding its cause.

This reservoir was drawn off about September 10th, and carefully cleaned. No water was pumped into it for nearly three months, and during this time it was fully exposed to the influence of the sun, wind, rain, and frost; and we should say that if algæ could be killed by drying and freezing, it certainly would have been in this case.

About November 27th, pumping into the reservoir from the filtering galleries commenced. The water from the galleries, in its slow passage through the soil, had taken into solution a large amount of the proper plant food, and, as a consequence, we have a body of water rich in all the elements which are necessary for algæ life, and not yet invaded by it.

We might now compare this body of water to a large pile of very dry wood in which the heat, generated by a single spark, causes the commencement of chemical action which extends through the whole pile, and only ceases when all the wood has been consumed. So in this body of water a single germ and the chemical force of sunshine creates a growth, which increases with marvellous rapidity, till the food material is used up and the plants die of starvation.

This water now is nearly destitute of plant food, and consequently no life is possible until it is again supplied, either by means of fresh water from the galleries, or what it may receive from the gases in the air, and also from the decomposition of the former growths, and not until the reservoir is again drawn entirely off and refilled will the algæ be so abundant. A little later I wish to follow the subsequent growths and point out the changes which occur.

The remarkable growth which commenced in the Brookline reservoir, in April last, was shortly after the reservoir had been emptied and filled with water from the galleries, and the cause for this growth was the same as in the case just mentioned.

And right here I wish to say a few words about the desirability of circulation of water in reservoirs.

In all reservoirs exposed to sunlight which are supplied from ground waters or from rapidly flowing streams, over rocky or sandy beds, circulation is a positive injury. Every gallon of such water contains food for millions of organisms, and each drop pumped into a reservoir increases the amount of organic matter to a corresponding extent.

In proof of this, you have only to look again at the remarkable growths in the Brookline and Newton reservoirs just alluded to. If a building was on fire, and to quench the flames a quantity of very combustible material should be thrown on it, it would not be difficult to foretell the result; and there is no more reason in pumping into a reservoir a quantity of fresh water, with the idea in view of improving the quality of that water in so doing.

As additional proof of the statement I have just made, I will relate a little experience we had in the Brookline reservoirs several years ago. Everybody said that circulation was what we needed to keep the water free from algæ, and one time after the reservoir had been carefully cleaned, this view of the case was given a thorough trial. It was in summer, when our daily consumption was about a million gallons. All the water, nearly, was pumped into one end of the reservoir, and made to pass through it. The amount of water in the reservoir during this trial was not much in excess of the daily consumption; in other words, nearly as much water was pumped into the reservoir each day, and drawn from it, as the reservoir contained, yet the algæ came in about the same length of time, and were fully as abundant. In consequence of this, the consumer received no water which was not laden with algæ; whereas, if the water had been pumped directly into the distribution, and only the surplus reached the reservoir, the water would have been good as long as pumping continued.

It is doubtful whether circulation improves water in any case, unless it is in ponds and reservoirs which have deposits of mud or decaying vegetable matter on the sides and bottoms, or water which has been drawn from such sources.

It may be interesting to say a few words in relation to the way these plants — algæ — are enabled to form their food, wholly or in part from inorganic matter.

By a little thought in this direction we at once see that all organic matter was once inorganic, and also that one kind of plant life is ever changing inorganic matter to organic, whilst another class of plants and animals are changing this organic back to inorganic again.

And it might be stated here, that not one particle of inorganic matter can be changed to organic without the chemical force which sunshine alone gives, and on this one fact hangs the existence of the entire vegetable world, and consequently life of all kinds. But to return; some plants cannot live and grow without the help of a certain amount of organic matter which has been provided by other plants, although they may create their own food to a large extent. Such examples we find in the forest trees, grasses, and all cultivated plants.

Other kinds of plants, however, are able to manufacture all their food from inorganic matter; to this class belong many mosses, all the lichens, and a large part of the algæ. By far the larger part of a plant body is composed of starch, or some of its kindred compounds; but in addition to this there must be a certain amount of iron. nitrogen, sulphur, and potassium, and often other elements.[1] These latter are present in a limited amount usually, but are as necessary as the nails and pins in the construction of a house; in fact, without some of them plant life would be impossible.

Starch, which has just been stated forms the greater part of the plant body, is composed of carbon and water, — largely of the latter. The carbon is derived, probably, mostly from carbon dioxide, which the water receives, to a large extent, from the air; and the iron, sulphur, nitrogen, etc., which ground waters contain in much larger quantities than surface waters, are taken into solution in the slow passage of the water through the soil. Nitrogen, however, may result quite largely from the decomposition of organic matter present in the body of water.

From this it will be seen that, although the iron, sulphur, etc., forms only a very small part of the plant food, yet those waters which contain these in larger quantities will support a much larger growth of plants.

Water which is deeply colored may be nearly destitute of life; in fact, color is

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[1] With the single exception of oxygen, the elementary constituents named above do not enter into the food of plants in an uncombined state; on the contrary, they are always absorbed in the condition of compounds, as water, carbon dioxide, and the

$$\left.\begin{array}{l}\text{Nitrates,}\\ \text{Sulphates,}\\ \text{Carbonates,}\\ \text{Phosphates,}\\ \text{Silicates, or}\\ \text{Chlorides}\end{array}\right\}\text{ of }\left\{\begin{array}{l}\text{Ammonia,}\\ \text{Potash,}\\ \text{Lime,}\\ \text{Iron,}\\ \text{Soda, or}\\ \text{Magnesia.}\end{array}\right.$$

In addition to these, many organic compounds are absorbed in particular cases, as in those plants which live in decaying animal or vegetable matter (saprophytes), as well as those which absorb the juices from living plants (parasites).

no indication of the presence of plant food. The vegetable solutions from which the color is derived may be that part of the former plant body which in itself is incomplete for plant food.

And following in this same line of thought comes the fact, that the more this organic matter which the plants have changed from inorganic is worked over and elaborated, the more complex becomes its structure, and more offensive it is in the process of decay.

Nearly all green plants during stages of decomposition are not troublesome or obnoxious to the sense, but during the decay of animals which feed on these plants, and fungi, even, the opposite is true, as we all very well know.

The plants of the Nosto family, of which the Clathrocystis is widely known, plants which probably obtain part of their food from the breaking up of other plants, are characterized by their unpleasant odors, and are much more disagreeable than the diatoms and plants of similar classes.

Now, I have noticed that the first growth which occurs in the Brookline reservoir after cleaning, and the same is true in the Newton reservoir, is not as noticeable, does not have such a decided and disagreeable taste, as growths which occur later. No one complained of the water in Brookline during the remarkable growth of last April, although a slight fishy smell was present; but in January of this year the water became so offensive, that it was necessary to exclude it from the town, and pump continuously, but by referring to the chart you will see that it was quite small in comparison.

The first growth are usually diatoms, protococcus, or plants of a similar class; plants which can form all their food from inorganic matter. These are continually dying and dropping to the bottom, where, during the process of decay, they furnish food for other plants and various kinds of animal life. These latter impart a far more disagreeable taste to the water. The trouble in Brookline in January, which has just been mentioned, was from infusoria which were feeding on the decomposing algæ.

I wish now to speak about the appearance of certain algæ in certain bodies of water, and also in relation to the danger of seeding one body of water with algæ growths from another. From my studies in this direction I do not think there is any danger of seeding one reservoir with the growth of another; or, in other words, if in a body of water exposed to sunshine the necessary food is present, it is utterly impossible to keep the algæ out; and, furthermore, the growth which is best adapted to live there will appear.

To illustrate this I will cite one case. Two years ago, last summer, the water in the Brookline reservoir was bad, and it was necessary to draw it off, and in so doing some of the water ran into one of the Boston reservoirs, owing to the partial stoppage of the overflow drain; but repeated microscopic examinations failed to discover any of this algæ in this reservoir. After the Brookline reservoir had been cleaned, over 100,000 gallons of water from the Boston reservoir was turned into it; but one month afterwards none of the algæ peculiar to the Boston water was found, and none have since appeared.

The very same plants which increased so enormously in both the Newton and Brookline reservoirs are often present in the Boston reservoirs and many other bodies of water, but only to a limited extent; yet if the food-supply was as abundant here the growth would undoubtedly be as large. The very infusoria

which gave Brookline the trouble in January is often found in Boston water, but not abundant enough to cause notice. And so I might go on for an hour, and point out cases similar to those just mentioned.

The question how they get there is not so easily answered, but a few observations of the possible ways of transportation from one pond to another may be stated. People who have studied the habits of frogs tell us that this harmless animal often travels from one pool or pond to another, making these journeys usually in the night; and from my own observation I know this statement to be correct.

The frog, in common with many reptiles, secretes a sticky fluid which covers his entire body; to this the algæ may adhere, and be carried long distances eventually.

Also the spores of the volvox, which many botanists claim must be dried before germination is possible, can be brought to the surface by the frog after one of his frantic plunges to the bottom, and dried sufficiently to suit the most rigid believer in this drying theory.

All birds frequent ponds, more or less, while some obtain their whole food from such places, flying from one neighborhood to another. In this way it is quite possible those minute plants may be widely scattered.

The thousands of insects which in summer are hovering over wet places may also act quite an important part here. It is quite probable, however, that the spores of these plants are more frequently distributed by the wind than by any other agent, perhaps not to germinate at once where they happen to be finally deposited, but to quietly wait a favorable time for their full development.

You can feel assured that if the food material fit for a certain class of algæ is present, that class of algæ will thrive there, and the only way to prevent this growth, as long as the water is exposed to sunlight, is to cut off the food-supply.

We know that absolutely pure water is incapable of supporting any kind of life. If there was some way of filling our reservoirs with such water, and maintaining this purity, algæ growths would be unknown.

I wish now to speak of the distribution of algæ in a body of water. Investigation in this direction shows that algæ are not usually, or in fact never, uniformly distributed. A sample from the surface or any other level may be wholly misleading as to the number of organisms present in the whole body of water.

To illustrate, I will give the results of a few examinations.

In the Brookline reservoir, July 20, in 50 c. c. of water there were 29,328 asterionella, and on the bottom, 38,916; on Aug. 2, at surface, there were 28,764, about the same number as on July 20; but on the bottom there were 340,938, or more than ten times as many as found here two weeks before.

A sample from Chestnut-Hill reservoir, taken Aug. 10, 1889, in same amount of water, showed at surface, 137,500; Clathrocystis, 12 feet below, 39,340; bottom, 5,076. While in same sample a diatom cyclotella was as follows: at surface, 3,800; 12 feet below surface, 3,384; bottom, 1,270, — much more uniformly distributed.

I might give you many other cases which differ as widely as those just mentioned, and also from other locations, but it hardly seems necessary.

And further, I have noticed that a growth which had been quite evenly dis-

tributed for several days, suddenly went to the bottom, and was found only in a layer about two feet deep. The whole growth was concentrated here, and the number was consequently very large.

In such a case, an average from samples taken at surface half-way down, and on bottom, would give too large results by far. And it is for such reasons as these that the results of several observers may differ largely. Another strange thing in this connection is, that one plant does not often flourish longer than a few weeks at one time. Where we find to-day a certain plant in abundance, a month or six weeks later it has, perhaps, wholly disappeared, and some other one heads the list, but only soon to give way to another; and so the changes are ever going on.

If the algæ in a pond or reservoir are to be studied thoroughly, samples should be taken as often as once a week, — even in this short time changes may occur, — and not less than three in number at different depths; a greater number would be better. A sample taken only at surface is not a true indication, and would lead to wrong conclusions, as has been shown.

After all, it may be said, What is the use of all this study? But it must be borne in mind that before a remedy can be suggested we must know the whole ground thoroughly.

A person cannot do an algebraic sum until he understands the principles of algebra. We do know that the exclusion of all sunlight will prevent the growth of green algæ. We have demonstrated this fully in Brookline.

About five years ago Brookline built a high-service system, and the water for this was stored in an iron tank fifty feet in diameter and thirty feet high.

The same growth appeared here which had caused so much trouble in the L. S reservoir, although no water from the reservoir was pumped into the tank. The frequent change of water, which was unavoidable in a tank of such small capacity, increased the growth, and it was even worse than in the low-service reservoir. Two years ago last August the tank was roofed over, excluding all sunlight, since which time no green algæ has been found, and the water has been free from taste and smell.

There is a class of plants, however, which thrive as well in complete darkness as in sunlight; but such plants are not able to make their own food, and are wholly dependent on food made by other plants.

Water which contains vegetable solutions in sufficient quantities with certain organic matter, might develop a very extensive growth in total darkness.

In the Brookline filtering gallery and high-service tank there is a slight growth of crenothrex, a plant of this kind, but in too small amount to do injury; and it is very doubtful whether waters which contain no more vegetable matter in solution than those furnished by Newton, Waltham, Hyde Park, and Brookline will ever be troubled by plants of this kind.

In closing, bearing in mind what is already known on this subject, a few suggestions might not be out of place.

Where it is necessary to store ground water, it should be in covered reservoirs or tanks, and in planning new works where water is obtained from such sources this feature should receive prominence.

This might lead to smaller reservoirs and larger pumping plants and force-mains. Be this as it may, a good water, and no other, is to be desired.

In construction of storage-basins and reservoirs for surface waters, all vegetable matter should be removed from the bottom and sides. They should also be built so as to allow for cleaning.

The algæ which is constantly falling to the bottom, unless removed, may give rise to subsequent growths of very unpleasant natures.

It is also desirable to arrange the basins and reservoirs so in case of an invasion of one by an organism which may make the water unpleasant, it can be isolated from the others without interfering with the supply.

If this paper, which I have just read, awakens a greater interest in this subject, and turns the attention of those who have the charge of water works more in this direction, it will not be in vain that you have listened so patiently this afternoon to the poor attempt to shed a little light on this partially explored region.

Prof. Drown. — I have listened with a great deal of pleasure to Mr. Forbes' paper. It seems to me that he has done an admirable piece of work in investigating a limited number of supplies with very great care, and comparing them with one another. The subject that most interests me, personally, is the relation between the growth of these organisms and their food. I remember hearing Mr. Forbes speak on another occasion with regard to the Brookline reservoir, when he gave more in detail than he has this afternoon the connection between the exhaustion of the food and the death, or the disappearance, of the organisms. I have had a similar experience in the water of the Hyde Park reservoir, which was experimentally shut off from the distributing system, in two divisions; that is to say, the water in the reservoir was exposed to the light, and that in the gate-house was kept secluded from the light, with the same water. The growth of algæ in the reservoir was very abundant at the start, but in a short time, within two or three weeks, they disappeared entirely, which agrees perfectly with Mr. Forbes' observations. In the gate-house, where there was no light, the growth never appeared to any noticeable extent, certainly not to an extent to give any annoyance. The chemical results at that time were very interesting. Mr. Forbes has alluded to the food that the plants derive from the ground waters, which, in the language of the chemist, is the nitrogen, in the form of nitrates. As many of you know, nitrogen we determine in four forms, — organic nitrogen, nitrogen as free ammonia, nitrogen as nitrites and nitrates; and the nitrates are generally abundant in these ground waters. The water at Hyde Park coming from the wells is moderately high in nitrates. As the algæ increased the nitrates decreased, and when the growth ceased or disappeared, that is, either sunk to the bottom or decomposed, the nitrates had disappeared also, entirely, coinciding with the observations of Mr. Forbes.

The diatoms are generally the most abundant forms in those waters which are high in nitrates, as in ground waters, which are exposed to air and light in reservoirs. In the Ludlow reservoir, of Springfield, we have entirely different conditions. It is surface water there, entirely free from any sewage pollution, or anything of that kind; but the region is a swampy one, and the reservoir has a muddy bottom. Here we do not find the diatoms abundantly, but rather algæ belonging to the Nostoc family; an occurrence which forms an interesting confirmation of Mr. Forbes' statement.

Mr. Allis. — I notice that most of Mr. Forbes' remarks with regard to the effect on the growth of algæ of covering the water were made in connection with ground waters. I would like to ask him if he believes water taken from an open pond like Spot Pond would be affected favorably in the same way.

Mr. Forbes. — I do not think it would. You would be pumping water from your pond into a covered reservoir or covered tank. That water going into this covered reservoir or tank would contain a certain amount of green algæ, and that algæ, when placed in a covered reservoir, would die. The decomposition of this algæ might make the water more offensive than when the algæ were in the live state. If you are continually pumping from a pond which is full of algæ into a covered reservoir or tank, they will be continually dying in there, and the covering would probably, instead of improving the water, make it worse.

Mr. Allis. — Some time ago we had a great deal of trouble in Spot Pond on account of a fishy taste. I would like to ask if algæ is found most frequently, or is especially bad, in those ponds where grass is pulled up by the ice in winter, and allowed to decompose on the bottom of the pond? At the time to which I refer we had a great deal of trouble with the water. It smelt very bad, and it tasted very bad. We were pumping the water then from the pond into a gate-house, and by raising the delivery-pipe about 12 feet and allowing it to come down through some screens, you could smell the water a good ways off, but it really made it very much better; therefore it occurred to me that possibly the trouble with us was more from the action of the gaseous compounds of the decomposing grass in the bottom of the pond. I don't know but what I was mistaken, however, and that it was the algæ, after all. You remember Mr. Ball's remarks at the meeting at Manchester, when he told us about taking the water from different heights of the pond, — in the winter taking it from the bottom, and in the summer taking it from the top. We have tried that at Spot Pond, also, and we think it makes some difference. We certainly have had no such trouble in Spot Pond as we had two summers ago. I think, perhaps, one reason is that we have had an abundant supply. The pond has been overflowing, and the little place where the trouble occurred has been covered deeper. I would like to know if this trouble in the water is always due to the algæ, or is it, in some cases, when the pond is in a bad condition, due to the gaseous compounds of decomposition?

Mr. Forbes. — Of course algæ are plants just the same as grass or anything else, and when any kind of vegetable matter is decaying it may impart an unpleasant taste to the water. The trouble the gentleman speaks of might be owing to the algæ, it might be owing to the animal life that was feeding upon the decomposing vegetable matter, or it might come from the grass, or whatever there was in the reservoir. It would be impossible to tell, without an examination at that time. But, as I say, algæ is nothing but a plant, of course, and that, the same as grass or anything else, might impart the taste to the water.

Mr. Hawes. — There are plants that grow in water that are not considered injurious, like the water-cress, — that is a very nice thing to eat, and it grows entirely in the water; and there are other vegetables which are nearly all water, like the turnip, which is 95 per cent. water. But is this vegetable matter that grows in the water, these algæ, injurious to the human system? If it is not, what is the use of trying to get it out, and covering the water over, and all that sort of thing, to prevent its growth? I would like to know whether it has been

chemically analyzed so anybody can tell whether it is injurious to the human system or not.

Professor Drown. — Perhaps it may comfort Mr. Hawes a little to know that the amount of solid organic matter in a surface water which is fairly turbid with suspended plants is excessively minute. In the water of the Ludlow reservoir, which I have already mentioned, there is frequently an excessive growth of blue-green algæ, so that one would naturally suppose that the water contained a large amount of solid substance. But when this green mass is thoroughly dried, the amount is less than one grain of solid, dry vegetable matter to the gallon. I can't say whether, if taken in large quantities, it might have any appreciable effect, but the dose is so minute I can't think, even if it were a strong poison, it would do any particular harm.

Mr. Hawes. — I don't think any one of us will drink enough water to get many grains. (Laughter.)

The President. — During the past summer, there was reported to me a case of a tank which was filled with a gelatinous substance so full that the outlet was closed, and the tank overflowed. I submitted some of this substance to Professor Sedgwick, and I will now ask him to give us the result of his examination.

Professor Sedgwick. — I hesitate very much to depart at all from the line of discussion opened up by Mr. Hawes, and more especially by Mr. Forbes. It has been very interesting to me, and with your permission I should like to say a few words upon that subject, before I take up the matter which you have suggested, in answer to the question, "Are these things of any harm, or are we really only getting more for our money, so to speak, when we have water which is full of vegetable matter?" That is a legitimate question, because many of these things are good to look at and not bad to eat. But, on the other hand, there is this to be said, that organisms which are good under some circumstances, every now and then give up the ghost, and when they decay other things come in that may, though we cannot say that they always do, produce serious distempers. Whether the grippe had its origin in one of these or not it is very difficult to say, but its origin probably had nothing to do with anything so harmless as water. The grippe began, you know, with the Czar of Russia, and he fights with dynamite, not with water.

The organisms which come in and do the harm are, of course, the germs of disease, if they do come in, and if they do any harm. But I cannot help feeling that the whole question of algæ in water is, after all, a good illustration of the fact that we in this country advance rather by working out our own experience than by accepting the experience of others, or what we might call "recorded" experience. Some one has pointed out that that is the American way of doing things; that we do not want to take any information from any other country, or from anybody else, but that we want to work it all out for ourselves. That is very admirable and very helpful in many cases, and we do accomplish good results in that way. But before the city of Zürich, for example, is supplied with water it goes to work and gets these organisms out. You cannot stop them from growing — (Mr. Forbes, I think, is quite right; they grow independently of many of the ordinary conditions which we are apt to supply to them) — but after that, what are you, as engineers, going to do about them? Are you going to continue to supply water containing such things as these, or are you going to do as

cities in Europe have done, a good many of them, already; that is, filter these things out, and deliver water free from them? That is a question, of course, for each water-works superintendent to answer for himself. But I would like to say this, that at the Lawrence experiment station, which the State Board of Health is carrying on in this State, some tanks have been running for about two years filtering the water of the Merrimac river at the rate of several hundred thousand gallons a day, some of the time as high as a million gallons per day, per acre, and every one of these algæ, every one of these animals, has been removed. Moreover, the bacteria, which may possibly produce colds, and the grippe, and diseases of one kind or another, — may possibly, I say, we don't know that those in water do; but which are things to be gotten rid of, and which Berlin and Zürich, and other places, are getting rid of, — have often been reduced from perhaps an average of 100 in the Merrimac river to an average of perhaps five or ten per cubic centimeter, by this simple plan of sand filtration. Now, it seems to me that after investigating this subject, and learning all we can about algæ, we have got to go farther, and get rid of them; and I leave that idea with you, as something to be thought over. Is it not time for our American cities to have as good water as the city of Zürich, which has not nearly the wealth of the city of Boston, I suppose, or as good as the water supplied to the city of Berlin ?

To return to what Mr. Brackett asked me to speak of, I have here a sample of the jelly he sent to me, and which, I suppose, he will hardly recognize at this time, as it is now in glycerine, for preservation. I want to say a few words about it, for this reason: it turned out to be a very interesting thing. It was found in a water-closet tank which it had filled so full that the tank could not be used. It was simply a mass of jelly of a greenish color, and at first sight it would, perhaps, suggest to anybody the Nostocs, or some other blue-green algal jellies. If I hadn't happened to have had a little experience with it before, I should have been puzzled by it, because I had never but once before seen anything like it. There is a lake near Boston upon which there grows in the spring a scum of jelly, sometimes in spots, several inches thick; great patches of this go floating around the pond, and it is a nuisance. My attention was first called to it two years ago, and on examining it I supposed I should find some of the ordinary blue-green algal jelly such as one sees sometimes in the summer in lakes and reservoirs. On the contrary, it turned out to be nothing of the sort. It was, in fact, a jelly stage of bacteria. That is the first case I ever saw on a large scale, and since, so far as I know, it is altogether new, I want to ask the members of this Association, — to which, this day, I have been very kindly admitted, and for which I wish to return my thanks, — I want to ask them if they meet with any cases of remarkable accumulation of jelly which they do not know how to account for, to do up a bottle of it and send it to me at the Institute of Technology. We have had, first, the case in a lake in Wellesley; second, the case which Mr. Brackett referred to us, in which the jelly had grown in a water-closet flushing tank; and third, since that time, — for it is curious how, when you meet with a thing, other examples of it appear, — in a case in Lawrence. A resident there has a tank in the top of his house, from which the house is supplied with water. This tank was so full of the jelly that the water would not run out. There was nothing bad about it, but it was a nuisance.

In all these cases we have the jelly stage of certain bacteria. I dare say it occurs rather commonly, but it has not been brought to the notice of biologists, so far as I know, and I should be very glad to get other specimens of it, because it is quite an interesting phase in the life history of these organisms. The practical bearing of it I take to be simply this: that in the right stage and under the right conditions the bacteria become altered. Their cells become partly mucilaginous, and thus produce a jelly, which, of course, if it once got into a city supply, might choke up all the ordinary service-pipes, and would be a great nuisance. It is fortunate that it is scarce; but I would like to repeat what I have said, if any one meets with a case of this kind of jelly, especially if growing in the dark, and having either no color at all or a faint greenish color, I should be very much obliged if he would send me a fruit-jar full of it.

The President. — Professor Drown has a few remarks to make, which he wishes to make now while the subject is fresh.

Professor Drown. — I have a specimen here which was handed to me by Mr. Noyes a month or two ago, and I am afraid it will go to pieces if I try to keep it for a month longer. Perhaps this communication might be made more appropriately by Mr. Noyes than by me; certainly it is his by the right of discovery. It looks something like a sponge or piece of dried moss. I think he told me it came from the interior of one of his large mains, — on the upper side, if I remember rightly. Our microscopical expert pronounced it to be the spongy remains of bryozoa, an animal which secretes mineral matter from the water in which it lives, and makes for itself a sheath as the coral polyps do; the earthy matter of this sheath remains after the animal has died. I thought it would be interesting to determine what was the chemical composition of this mass, since the mineral matter in it must have come from the water. When Mr. Noyes brought it to me, it was moist and had a very pleasant, mossy odor. Now that it is dry it has no odor. The organic matter in the mass is only about 18 per cent. The residue contains about 39 per cent. of silica, about 23 per cent. of oxide of iron, and 3 per cent. lime. And what is very remarkable, it seems to me it contains, in addition, 33 per cent. of oxide manganese, a substance which we did not know was present in the Newton water. Perhaps on concentrating a large quantity of the water by evaporation we may be able to detect the presence of manganese. The animal could not get the manganese from any other source than the water, except, perhaps, from the iron pipe to which it was attached. But this latter suggestion seems to me very improbable. I anticipate Mr. Hawes' question as to the possible injurious effect of manganese on the system by referring him to Mr. Noyes, who can tell him about the health of the people of Newton.

Mr. Noyes. — My attention was first called to the presence of this growth in the water-pipes when cutting out a section of 16-inch and 24-inch force main in order to make other connections. The coating was apparently as thick as the specimen when it was moist, from three-eighths to half an inch; it was thickest on the top, gradually became thinner on the sides, and on the bottom there was very little. Not having known of it before, and having occasion to again break out the main, I took this sample from the 24-inch pipe and gave it to Professor Drown. The conditions are, the force main is near the pumping-station, and is subjected to a constant water pressure of about 80 to 87 pounds. I also found imbedded sev-

eral small mollusks about one-fourth inch in diameter, of about the same shape as a quahaug or a little neck clam, and these were apparently alive.

It interested as well as puzzled me to know how this class of life could be sustained under such conditions. I supposed it must be peculiar to our supply, which is, as you are probably aware, ground water, until I observed the same growth and shell-fish in a cast-iron special which had been taken from one of the water mains of the city of Somerville, which is supplied with water from the Mystic Division of the Boston Water Works, and is a surface water-supply.

Shortly afterwards, when putting in the foundations for a bridge over the Charles river, they dug out a large rock that had been imbedded on the bottom, and on the portion of that rock which was above the bottom of the river-bed I found a mossy growth somewhat similar in fibre to this, and I found imbedded in it this same mollusk, which led me to conclude it could not be due entirely to the conditions of excessive pressure, because in this case it was but two or three feet below the surface of the water. Of course Professor Sedgwick or Professor Drown can explain fully that which seemed to me very singular at the time.

The PRESIDENT. — As this seems to be a question of clams, I don't see but we shall have to refer it back to Mr. Hawes, who I think is authority on that subject. (Laughter.)

Mr. NOYES. — As Mr. Hawes does not rise, perhaps I can say a word or two which may throw some light on some facts which Mr. Forbes has stated. I don't know but what all the members may be fully aware of the conditions, but in looking at the diagram which Mr. Forbes exhibits for the months of October, November, and December, it would appear as though this growth in the Newton water was very slight. I presume from Mr. Forbes' explanation that these samples were taken from the reservoir, but the Newton reservoir at that time was empty, and we were pumping directly into the pipes. Now, while Newton water is ground water, yet it is exposed to the light and sun in a filter gallery, which is nothing more than an elongated well. During these months we were pumping directly into the pipes day and night, and yet there has been no time during the existence of the works when there has been so much complaint of the odor and taste of the water as there was at that time.

Since filling the reservoir the annoyance has not been so great, although there have been complaints from time to time of the odor from the water. I merely make the explanation because I see that the growth is somewhat high on Mr. Forbes' diagram for Brookline, and would appear to be low for Newton.

Touching on another point, I think Professor Sedgwick referred to the effect of a dry season. I recall that the first real serious trouble we ever had with the Newton water was after a dry season; I think it was in 1883 or 1884, when for several months we were pumping continuously from the filter gallery, and the level of the water in the filter gallery during this period was maintained very low. During those months the growth in the gallery was considerable, and the men were continually employed in cleaning it out. The drought continued until late in the fall, and the water in the gallery did not rise to its normal height until well into the winter, when the high water in the river held back the ground-water, so that it was unusually nigh in the spring, when we began to have serious complaints of the unusual odor from and taste of the water; and the explanation

seemed to me at that time to be, in cleaning out the growth in the basin it had been thrown upon, and had become partially incorporated in, the sand of the banks in the shape of a fine powder which the water had taken up. This is only an idea suggested to me without any intelligent foundation for it.

I recall one or two cases where we have found growths of a jelly-like substance in tanks. As spoken of by Professor Sedgwick and our President, I supposed it to be due more to lack of cleanliness on the part of the householder than to anything else. I believe the tank was cleaned out, but the same jelly-like substance reappeared again. I have also found these jelly-like clusters in the filter gallery, but I do not know whether they have any relation to what Professor Sedgwick has in mind. The next time it occurs I shall be pleased to send him a sample.

Professor Sedgwick. — I think that perhaps I ought to say that there are many jellies such as Mr. Rafter has spoken of. We are all familiar with the Nostoc jellies, etc., and I daresay Mr. Noyes' jellies in the filtering gallery were of that kind. They probably were not bacterial jellies such as I have described, because the bacteria in that gallery have not been very abundant. But Mr. Noyes has brought out what I was going to ask Mr. Forbes if he had noticed, and that is this, namely, the condition of the Newton water during October, November, and December, when the chart shows, of course, nothing in the reservoir, because it was empty. At that time the smell of the Newton water being bad, one of my students, who lives there, brought me some of it. As I had frequently seen the Newton water before, I examined it again with interest, and to my surprise found it almost a pure culture of Asterionella, the very diatom which has been discussed. I sent out to the filter-gallery for a sample, and found the filter-gallery water also full of Asterionella. It seems to me to confirm Mr. Forbes' idea, that the temperature was not the main factor, because the filter-gallery is pretty constant in temperature, and yet in the summer this diatom was not there, while in the fall it was in great abundance. During the summer there are filamentous algæ, green slimes, and pond scums present in the filter-gallery to a limited extent, and I believe they are raked out from time to time. My idea of it is that in the fall these died, and afterwards furnished food to an extraordinary number of diatoms, which then took their place in the filter-gallery, and of course were distributed to the city.

METHOD OF CLEANING THE DISTRIBUTING RESERVOIR OF THE NEW BEDFORD WATER WORKS.

BY

R. C. P. Coggeshall, Superintendent New Bedford Water Works.

Read March 12, 1890.

The distributing reservoir of the New Bedford Water Works has a surface form of a trapezium and covers an area of about five acres. The earthen embankments which compose its sides are fifteen feet in width at the top, with slopes inside and outside of two feet horizontal to one vertical. The general dimen-

sions through the middle are about 345 feet by 255 feet. The bottom is the natural surface left after excavation, and is gravel well filled with clay. The vertical height from the bottom to the level of the top of the embankment is 20 feet. A depth of 18 feet constitutes a full reservoir, and that volume contains 14,957,101 gallons.

During the month of April, 1888, this reservoir was drained for the purpose of making extensive repairs to the well of the gate-house, and also to the stone facing on the inside slope walls. While these repairs were in progress, the side walls and bottom were thoroughly cleaned. It is now my purpose to briefly describe the manner in which this work was done.

At a convenient location on the south inside slope, a runway four feet in width was placed. Two-inch planking was used, and a ledge fastened to the sides to prevent the truck from slipping off. At the top of the slope this runway connected with a level plank platform, extending across the top of the embankment and continued to a convenient distance beyond the foot of the outside slope. Near the end of the platform and well beyond the outside slope was a hole of convenient size, through which *débris* was dumped some fifteen feet to the ground beneath.

The runway on the inside slope allowed the use of a truck 2½ feet by 5½ feet, constructed of 2-inch planks, having three cross-pieces underneath 2 inches by 6 inches, and two cross-pieces on top 2 inches by 6 inches placed edgeways, — one on the lower edge of the truck, the other in the middle. This allowed the placing of two tubs upon the truck at the same time for haulage up the slope without danger of either slipping. The truck ran on six large casters, having 4-inch wheels.

The haulage was made by means of a single rope spooling over a 4-inch derrick wench without gearing. This wench had a crank on each end and required two men to operate. A third man manipulated the slack of the rope. By this method the truck was operated with ease, and more rapidly than it could be done in any other way.

Six tubs were used. These were made from 50-gallon oil casks cut in two. For convenience in lifting, handles were placed on opposite sides.

In eight days from the time the reservoir was discontinued from the distributing system the bottom was in condition for cleaning. Nearly all moisture had then evaporated from the material to be removed. A vegetable deposit, averaging from a quarter to a half an inch covered the bottom. At the foot of the slope walls, especially in the corners, there was found a large quantity of gravel which had become displaced from beneath the stone lining of the slope by reason of the continued wash of years upon it.

All the material to be removed was thoroughly scraped into convenient piles and then transferred to the foot of the runway by means of wheelbarrows. Here it was placed in the tubs, they being upon the truck. The truck was then hauled to the top of the slope and run along the platform to the hole near its end. The material was then dumped, and the truck, together with the tubs, quickly returned to the bottom of the slope. The dump heap thus formed beneath the platform was afterwards removed by carts.

Mr. Noyes. — I would like to ask Mr. Coggeshall how long a time the deposit he speaks of had been accumulating.

Mr. Coggeshall. — Twenty years.

Mr. Fuller. — I should like to ask Mr. Coggeshall if the running down of the gravel from under the paving of the reservoir did not allow the paving to settle out of place.

Mr. Coggeshall. — Yes; some eight years or more ago the wall had become pretty thoroughly demoralized, and we then lowered the reservoir so that there was only about 4 feet of water left in it, and repaired it at the time, thoroughly grouting the joints, so that the face of the wall now is in very good condition.

The President. — I hope if any of the members have had any experience in cleaning their reservoirs, they will give us the benefit of it. I think the city of Newton has lately cleaned its reservoir, and perhaps Mr. Hyde will give us some information as to how the work was done there.

Mr. Hyde. — Our reservoir was cleaned last fall, and in a similar way to that which Mr. Coggeshall speaks of, with the exception of the wheels, buckets, and derrick. We had rather more of an accumulation of vegetable matter in the bottom of the reservoir, I should think, than he had. And when our reservoir was cleaned, we also had occasion to put in two check valves in the gate-house, which were in rather a bad condition.

EXPERIENCE WITH A THIRTY-INCH GATE.

BY

Hiram S. Nevons, Superintendent, Cambridge. Read March 12, 1890.

Mr. President, — As this is an experience meeting, I will relate mine with a 30-inch gate, located within 150 feet of the fountain at Fresh Pond and on the Stony Brook pipe line.

This gate controls the inflow from Stony Brook through the fountain into Fresh Pond.

From the first use of this gate some three years ago, it was found that as soon as the gate was opened far enough for the water to commence flowing, a surging motion commenced with such force as to hold the gate rigid for half a minute, then it would relax and become quiet, and one man could easily turn the gate, perhaps one turn, when the surging would again commence with greater force, and it would be almost impossible for two men to move the gate until it became quieted.

This would continue until the gate was open about 6 inches.

Great care was taken in opening the gate slowly, but nothing that suggested itself seemed to help the condition of things. The shock was so great that within one year ten joints were started within 1,000 feet of the gate, and it became a source of dread when it became necessary to manipulate this gate.

From the first observation of this trouble it was supposed to be air in the pipe, and great care was taken in going to all of the air valves and opening them; but no indication of air was observed. This was repeatedly done.

Still, theory, and every one who was asked in regard to it, would reply, "There is air in the pipe."

Thinking that perhaps the trouble might arise from other causes, and not presuming to say that theory and experienced men were *wrong*, yet, thinking it caused by the receding and returning of the water as the gate was opened or shut, an 8-inch by-pass was placed around the 30-inch gate, and now when the flow is started or shutting off is done with this 8-inch gate, no trouble from a surging motion is experienced, and the gate is manipulated with great ease with one hand. Every one connected with the intake of Stony Brook supply is happy, as far as manipulating the gates is concerned.

Referring to the *blue-print* the City Engineer has kindly furnished me, of which I have a few copies and will pass them around, you will see that the distance from Stony Brook dam to Fresh Pond is about 7½ miles.

The *elevation* of Stony Brook is 81.—, and at Fresh Pond 16.85, making a head of 64.15.

You will observe that near Fresh Pond, *sections* marked "Dexter avenue" and "Holworthy street," the grade rises very quickly. It was supposed when this pipe was laid it would act as a *siphon*, but on opening the gate at Fresh Pond the water would rise about 6 or 8 feet from the pipe, and remain so 3 or 4 minutes, when it would rapidly fall away.

It was found that, with all the care that could be exercised in opening, the flow *would* break at "Holworthy street" and "Dexter avenue." Having occasion to open the 30-inch gate a few days ago, the 8-inch gate was first opened, then when the 30-inch was opened about 3 or 4 inches the 8-inch was shut, while the 30-inch was being slowly opened. The result was a steady flow without any perceptible change, except a steady increase in the flow until the gate was wide open, and so remained.

The PRESIDENT. — I will now call upon Mr. Holden, of Nashua.

INEQUALITIES IN WATER RATES.

BY

HORACE G. HOLDEN. Read March 12, 1890.

MR. HOLDEN. — Having lately received communications from different parties in relation to water-rates, stating that they were about revising their rates, and asking for an exchange of mine, I have written a short article on that subject which, perhaps, may be interesting.

After a water department has been in successful operation long enough to reach that point where the income derived is sufficient after paying the interest on the debt, together with the annual cost of maintenance and yearly construction, and still have a balance on hand for a sinking-fund, then a reduction of the water-rates is usually in order. Now, having lately had occasion to revise our tariff of water-rates, together with the changing of some of our rules and regulations, I was surprised to find, in looking over a large number of rates from different cities and towns throughout the country, that, as far as I could discover, no two places had rates alike, and but very few had even the same rules and regulations. There was, especially, a great diversity in the manner of making charges for family rates, and while many based their charges on the number of

persons, others had a specific charge for each family, irrespective of the membership; others graded their charges by the number of faucets; some by the assessed valuations of the property, and others by the number of feet of frontage; while quite a number of places based the family rate by the number of rooms in the house. I did not find a great diversity in the charges for shops and stores; and in most places the metered rates were well proportioned to the specific charges. Still, I noticed that the rates in the very large cities were much more simple and concise than they were in many of the small towns. As an illustration of the way in which some small towns get up an elaborate tariff of water-rates, I will relate an instance that came under my own observation. Before a company has secured a franchise to construct and operate a system of water works for a town, it is customary for the town council to establish a tariff of water-rates, in order that the company may not be extortionate in their charges to the consumers. Now, I was once interested in some works that were about being put into a village which was the centre of a large farming district located in one of the prohibition States in the West. I have with me the tariff of rates which were established by the town council for this place. It fills five closely printed pages, and comprises almost every use to which water could be placed, even in our largest cities. I will read for your benefit a few of the charges.

There are some 150 or more different charges for a small town; they are arranged alphabetically, and I will only read a few of them. It starts off with alcohol, 10 cents a barrel (laughter); ale-houses, $12.50 to $45; bakers, each barrel of flour used daily, $5; bar-room, $12.50 to $45; barber-shop, first chair, $5, each additional chair, $2; private baths, cold, each tub, $4; bath, private, hot, each tub, $5; baths, hotel and boarding-house, $8, cold; bath, hotel and boarding-house, hot, $10; public baths, $12; brewery, each barrel brewed, 5 cents (laughter); boarding-houses are 45 per cent. more than private residences; brick-yards, churches, candle factories, cigar factories, coffee saloons, are $12.50 to $45; a confectionery saloon is $15 to $100; then there is concrete per cubic yard; and so it runs on, distillery, dyeing and scouring, down to rectifying; and then it comes to residences, and there the charge is by the rooms. For a residence of one room it is $4.50; of five rooms, $5.25; for a residence of 11 rooms it is $13, and each additional room is 95 cents. (Laughter.) Restaurants are $15 to $100; saloons, $12.50 to $45; slaughter-houses, soap factories, powder factories, tobacco factories, vehicles, vinegar factories, washing bottles, and finally winds up with a wine cellar, which is $15. (Laughter.)

Now, as I previously remarked, this town was situated in a prohibition State, where the prohibitory law was enforced, and there was not in the town, and probably never will be, either a bar-room, brewery, or distillery; neither was it probable that there would ever be any kind of manufacturing ever carried on in the place. So that the only revenue from which the company could expect to ever derive much income from, besides the hydrant rental, was the family rates. I suggested to the town council that these charges would be more appropriate if the town was only situated in the State of Kentucky; but I do not believe that our friend Rogers here would consider them suitable for even his State of Maine water works. I afterwards made a compromise with the town council by which they allowed the water company to charge $10 for each family, irrespective of size; $5 for a hose, $5 for a closet, and $5 for a store. And if at any time water

should ever be wanted for any other purposes, and a satisfactory agreement could not be made between the company and the consumer, the company could have the privilege of setting a meter, and receive thirty cents per thousand gallons for the water used; and this agreement has ever since proved perfectly satisfactory to both parties.

Now, I will take another illustration nearer home. The Lowell Water Board, in their seventeenth annual report, just published, have prepared a table giving the charges of 33 cities for water for a family having all the modern conveniences; viz., family rate, water-closet, bath-tub, set-basin, set-tubs, horse, cow, hose. No two of these 33 cities have their individual charges alike.

I have the table here which will show the difference in the rates right here in New England. New Bedford has the lowest, according to this table, \$16.25, against Cambridge, \$41 for the same fixtures. New Bedford and Cambridge (referring to Mr. Coggeshall and Mr. Nevons) are here together, and they can speak for themselves.

Mr. Nevons. — We have no such rate.

Mr. Holden. — It is so, according to this table, which has just been published.

Mr. Nevons. — That table is not correct.

Mr. Coggeshall. — It is only \$13.50 in New Bedford.

Mr. Holden. — It gives here in this table the rates for 33 different places. For instance, here is Concord, N.H., and Fitchburg, Mass., which have a population of about the same; they both have an unlimited supply by gravity, and the rates of Concord are \$19, and the rates of Fitchburg are \$34 for the same fixtures, according to this table. Take three other places, Cleveland, Buffalo, and Chicago; those three have an unlimited supply, and draw from the same source, as you might say; that is, they draw from the Lakes. The rate of the city of Cleveland for these fixtures would be \$21.50, while Buffalo's would be \$44.50, and Chicago's would be \$42.25. Take the rates now in Lowell and Lawrence; they have an unlimited supply, and they draw from the same source. Their rates are alike, \$23, though their charges are entirely different, the total charges, however, amounting to the same. So I find the charges varying all the way from \$16.25 up to — I think that the highest is Portland, Me., where they have an unlimited supply, which comes right in by gravity, and there the charge is \$42.

Now, I have no doubt but what many new places labor under great disadvantages in establishing their first tariff of water-rates, and I wish now to offer a suggestion that this Association take the matter into consideration of recommending a form of rates by which any new works, or even any old works who are about revising their rates, can get some good practical ideas.

Mr. Winslow. — I would like to ask Mr. Holden if these rates he mentions are the limit for a family. For instance, a person has a house, and puts in his fixtures, where they have a rate of six or eight dollars a faucet; can he put in all the fixtures he sees fit and not have the rate exceed the \$23 or \$25 — is that the limit?

Mr. Holden. — I take this out of the report of the Lowell Water Board, which has just been published. It is a table to show that their rates in Lowell are about as low as the average. There is a family rate, water-closets, bath-tubs, set-basins, set-tubs, horse and carriage, with use of hose, cow and garden

hose. These are the total rates, I suppose, according to the tariff of rates that they have got from different cities; that is what it would amount to for an ordinary family with those fixtures.

Mr. WINSLOW. — I don't think you quite get my idea. That is what it would amount to under those conditions; but supposing a man were to put in more fixtures, would the rate be increased over and above that?

Mr. HOLDEN. — The probability is that it would be; I don't know anything about it, however. This is as I get it from this report.

Mr. WINSLOW. — The reason I spoke of this was, in some towns and cities where they make a rate of $25, they allow parties to put in as many more fixtures as they see fit, if the house is only used by one family, and it will not exceed that price.

Mr. HOLDEN. — That is the way it is done in most places, I think. Twenty dollars is our limit in Nashua. They can put in as many fixtures as they wish; we make no extra charge for second closets, for instance, and make no charge for bath-tubs, and no charge for set-basins, no charge for set wash-tubs. Many cities make no charge for set wash-tubs; I should think half of them do not, while others do. Some charge $2, some charge $3, and some charge $1, and I see some of them charge $2.50. And for the regular family rate, which is simply, I suppose, for one faucet in a house, the charges are all the way from $5 to $20. The city of Buffalo charges $20, Albany charges $18, Brooklyn charges $16, Portland charges $10, Yonkers, $10; most of the others charge on an average about $5 or $6; Salem is the lowest, $3.50, but it makes up on other things, so the total is $25.

Mr. ALLIS. — I would like to ask Mr. Holden if he really means they charge as high as $20 for one faucet. Did I understand that correctly?

Mr. HOLDEN. — As I read it here that is what it says in this table.

Mr. ALLIS. — For one faucet $20! I would like to be a member of that company. (Laughter.)

Mr. HOLDEN. — The family rate for the city of Buffalo is $20, for the city of Chicago it is $19. All I know about it is what I read in this table. This is supposed to be authentic.

Mr. HAWES. — It is a little curious to look these things over, when we know how tables are sometimes made up. Just look at this now. For the luxuries of life, like a bakeshop, they charge $5 a barrel, while for the necessities, like a brewery, they charge five cents a barrel. (Laughter.) And, then, Mr. Holden goes on and tells us there is no brewery in the place. Now, if that isn't an inducement for breweries to go there, I don't know what is. (Laughter.) We had a case in our town which was somewhat interesting. We charged $2 for every cow that a man kept. There was a man in the lower portion of the town who had three or four cows, and the city put one of these low drinking-fountains right in the street in front of his house, at the junction of another street, and it wasn't but a little while before the man had twenty cows, and he watered them all at this stone fountain. (Laughter.) It made a very dirty place there, and people complained, so when a short time after we had an order to put in a fountain half a mile below there, we decided we would remove this one to that place, and put in the place of the old one, one of these high tank fountains, where you can water your horse without unhooking the check-

rein, but you can't water your cows unless you put up a staging for them. (Laughter.) The man saw what we were doing, and he came out and made a terrible fuss about it; but Mr. Kieran went on and hurried up the job. The man threatened to turn the whole Water Board out the next year, but Mr. Kieran kept right on just the same. (Laughter.) It is astonishing how the quality of the milk has improved since we made the change. (Laughter.) But the milkman was so mad that he died in less than three months (laughter), and the business was sold out.

Mr. Richards. — I think this table will bear correcting in a good many particulars. I find that New London is $2 too high, according to this list; if the correct figures were given it would be the lowest one on the list. There is a mistake of $10 in Cambridge, and New Bedford is $2.75 too high. Judging from these cases I think that table will bear revision.

Mr. Steben. — We have experienced a great deal of trouble with regard to our water-rates. Our system is to charge according to the number of rooms and the number of inmates in the house. For instance, for a house of seven rooms, with seven in the family, the rate would be $14; we merely add the number of rooms and the number of the family together. In some cases it is all right enough, but you take, for instance, a man who is getting about $1 a day, and has two or three children, he would be paying as much as a man who was getting a good income, and of course he can't very well afford to pay it. I have placed this matter before our directors very often, but unfortunately they cannot see their way through; they don't know how to regulate it; and I thought I would ask some of you gentlemen what system you think would be proper, and what you think about this system of charging according to the rooms and the inmates in the house. The population of our town is about 9,500. We have 497 consumers, I think. I might add also that we supply the Grand Trunk Railway, and of course the corporation. We get $50 each for the hydrants, and we have 84 hydrants now, so they pay us $4,200 a year, and the Grand Trunk $2,050. We have a total revenue of about $16,000, and the running expenses are about $5,000. We think we are pumping a great deal too much water for the number of consumers we have. During the last month we have pumped 25,875,000 gallons, that is a daily average of a little over 870,000 gallons a day of 24 hours, with a consumption of 42½ tons of coal, making a daily average of 2,500 pounds.

Mr. Hawes. — How much is the consumption *per capita?* Have you figured that out.

Mr. Steben. — I don't know the consumption. I believe there is a great deal of waste water, and that is what we want to ascertain at the present time. I might also state that they have put in a system of sewerage there which we have had a great deal of trouble about. The company and the town people are in dispute about it. They started the sewerage system last July, and they claim that we are obliged to supply them with water free of charge for flushing purposes. Of course we refused to supply it, and they went on and attached their hose to the hydrants, and got all the water to flush their drains. We found they were taking some days from thirty to forty thousand gallons which they were using in that way. We think it is wrong that any one should try to cheat the company in this way.

Mr. HAWES. — Do you use the meter system?

Mr. STEBEN. — Unfortunately, no. We have only three meters at the present time, which I have put in, I may say, against the wish of the company. Some of our directors are willing to invest in meters, but some are not, thinking they won't gain anything by it. I have found by the use of one meter that a man who has been paying only $30 a year, has been using water at the rate of $125 a year.

Mr. HAWES. — Make your consumers pay for your meters, and they won't waste nearly so much water.

Mr. STEBEN. — It would be a saving in fuel also. I would like very much to hear from you gentlemen on this subject.

Mr. ANDREWS. — How many thousand gallons of water do you use a day?

Mr. STEBEN. — A little over 870,000 gallons a day.

The PRESIDENT. — You have about 500 consumers?

Mr. STEBEN. — 495.

The PRESIDENT. — Would there be about eight persons to each taker, on an average, or about how many? You don't mean only 500 people?

Mr. STEBEN. — No; 495 families.

The PRESIDENT. — Would eight be a fair average for the number of people in a family?

Mr. HAWES. — It is in Canada, you know; you had better call it ten, I guess. (Laughter.)

Mr. STEBEN. — No; that would be rather too high; six would be about the average.

The PRESIDENT. — If it was eight it would be about 220 gallons a head.

Mr. HAWES. — Take the whole population, and it would be about 100 gallons. That is the way we get at it usually in the States, figure it *per capita*. We have 100,000 inhabitants in Fall River, and we use 60 or 80 gallons *per capita;* while in the big city of New London (laughter) they use about 100 gallons, the same as you do.

The PRESIDENT. — I will now call upon Mr. Noyes, of Newton.

AN EXPERIENCE IN EXCAVATING IN QUICKSAND.

BY

ALBERT F. NOYES. Read March 12, 1890.

Mr. NOYES. — Mr. President, some years ago I had occasion to make an excavation in material known as quicksand, some 15 feet deep, near buildings. If the excavations were made in the ordinary way, a settlement of the foundations would be likely to occur, so I adopted the following method, which in my case proved successful; and I see no reason why, under similar conditions, and in a great many cases, it could not be used to advantage. The excavation, as I have said, was about 15 feet deep, about 60 feet in length, and 8 feet wide. Usually below these veins of quicksand there are veins of a coarse material which form ready conductors for the water, and the vertical distance through the quicksand is usually less than the horizontal distance; the ground water has the least resistance in the vertical direction, and tends to soften and take up the quicksand with it. If the water is drawn out, or the water level lowered below the bottom of the trench, this fine material becomes compact, very much like

clay, and excavations can be easily made with perfect safety, and the use of a light sheeting. In the case I refer to I used fourteen 1½-inch pipes, which were driven equidistant about the excavation to be made with the ordinary perforated well point, having attached outside a fine-mesh brass screen. They were driven into a stratum of coarse material from 35 to 50 feet below the surface of the ground. The pipes were ganged together, and attached to a common plunger pump, and the water was drawn down. I might state that the normal level of the ground water was within some 3 or 4 feet of the surface of the ground, so we had to draw the ground water down some 10 or 11 feet. We found by test tubes outside of the gang that we could readily hold the water to a level, which insured the excavations being made without any difficulty whatever; in fact, the banks were dry, and the lower portion of the excavation was very firm. In this case the well points, after we used them, were sold to other parties at nearly the first cost. The pipes, which were taken from the stock at the pipe yard, were returned and used over again, so that there was little loss in that way; and the whole cost of driving the pipe was about $18, so that the expense of that method was really less than sinking a well outside of the excavation in the usual manner.

Mr. Allis. — As Mr. Noyes has had some experience with a certain locality I am acquainted with in Malden, where we have got a lot of pipes driven, and as I expect to do something similar to what he has been telling us about, I would like to ask him whether he thinks if I was to drive six or seven or eight pipes I would be able to do as well as he did, and get rid of the water in that way?

Mr. Noyes. — This gang of pipes surrounded the excavation.

Mr. Allis. — Seven or eight of them?

Mr. Noyes. — There were fourteen of them, — 1½-inch pipes. In this case the stratum was not as coarse as I would liked to have had it, so I drove these pipes with well points; that is, perforated points with the brass strainers. In your case, I would say that in our experiments at Malden we held the water down 18 to 22 feet in the immediate vicinity of the well. That is, should you adopt the same method, under the conditions that existed in the Malden test, you could hold the water from 16 to 20 feet inside of such a gang of wells, below the surface. In the Malden case the level of the ground water before pumping rose to the surface. Of course you can't ordinarily get a vacuum above 22 or 23 inches. If you have tubes enough you can hold the water down somewhere from 16 to 22, according to the coarseness of the feeding material or medium.

Mr. Allis. — May I ask what kind of a pump you used, — how much of a pump?

Mr. Noyes. — It was a Blake Tank Pump. We got from 90,000 to 100,000 gallons in 24 hours, and we pumped continually during the work. I forget now just the size of it.

Mr. Allis. — We would have to have quite a pump to handle the water there, — more of a pump than you used.

Mr. Noyes. — It would depend upon how much of an excavation you wanted to make. For instance, in your case, where we had, I think, thirteen or fourteen 2½-inch tubes, we were pumping between 800,000 and 1,000,000 gallons in 24 hours; but during the pumping we held the water down in the test tubes that lay within the area of the ganged wells, I think, about 20 feet. We got a 23-inch vacuum.

Mr. Allis. — I see what you are driving at; I get the idea, but what I wanted

to find out was, if I go to work and do that, how large a pump I have got to put on there. As I understand you now, I will have to get quite a large pump, because we are doing that very thing now, — we are drawing the water down 20 feet, and we have a million and a half of gallons pump. I want to know with how small a pump I can handle that sort of thing.

Mr. Noyes. — I think it depends upon how large an area you want to make your excavation in.

Mr. Allis. — It is in the sand, about 60 feet away from the pump station, where our wells are.

Mr. Noyes. — How long an excavation?

Mr. Allis. — I want to make one 20 or 30 feet in diameter and 10 feet deep, for an open well. That ground is pretty bad quicksand, you know.

Mr. Noyes. — I should think under these conditions, with all the conditions as I have seen them at your place, you would want a pump which would pump well on to a million gallons.

Mr. Allis. — That is what I wanted to get at; I am much obliged.

Mr. Winslow. — Wouldn't it be better for Mr. Allis to put in some sheet plank around his excavation, make a rib, something of that kind, suppose it is a round well, and use a centrifugal pump?

Mr. Allis. — That is a plan I had thought of in my own mind, but hearing this from Mr. Noyes, I thought I would like to get some information in regard to it. I think, myself, something of that kind would be better for me.

Mr. Noyes. — The main value of the method I suggest is where you have buildings near your excavation, and you don't want to run the risk of drawing the material from under their foundations. In this way there is practically no running of the material, that is, the sand will not run, if you have held the ground water down to that point, because the vein of sand is ordinarily fed from that vein of coarser material beneath.

The President. — Mr. Allis speaks of pumping now from a number of wells. I would like to ask him how large an area these wells cover. If I understand correctly, Mr. Noyes refers to pumping the water from a comparatively small area during an excavation; while in your case I think your wells cover somewhat of a large area. In a smaller area you would get a smaller quantity of water, and by having the driven wells around the well, you would not draw the sand into the well with the water, as you would with the centrifugal pump.

Mr. Allis. — I would say that we have 51 wells arranged in rows and gangs, so that they occupy a space, I think, about 100 feet in length by 60 feet in width — perhaps a little less in width, I am not quite sure about that. My proposition is to put down a well some 50 feet beyond the gangs, and 60 feet from my house. I have a very bad quicksand there, and I don't want the foundations to give way. I don't know but I could put in some small pipes and a small pump, but perhaps if I should sheath it and hold it, and put on a centrifugal pump, that might be the cheapest. Or I might put my big pump on there; perhaps I can do that.

Mr. Chace. — I have prepared a short sketch of an experience with artesian wells. There was an account of this in the last report of the Water Commissioners of Taunton, which I think you have all received. It contains a map, and if any of you have not received a copy, I should be glad to send you one.

ARTESIAN WELL EXPERIMENT AT TAUNTON.

BY

GEORGE F. CHACE. Read March 12, 1890.

To give a full history of this well and the reasons for the experiment would consume an hour. A few of the most interesting features are here briefly stated.

A contract was made with the Pierce Artesian and Oil Well Supply Co., of New York City, to drill an 8-inch hole for a certain price per foot, the water department to furnish steam for their engine. The hole was to be not less than 50 feet, nor more than 1,000 feet, at the stipulated rate. Other details of the contract it is not necessary to mention.

Drilling was commenced at noon, April 5, 1889. The first 50 feet consisted of sand and fine gravel with more or less clay; the last 10 feet being mostly clay. This was followed by 2 feet of water-bearing sand. No attempt was made to determine the quality or quantity of the water at this point. Several driven wells had already been put down into a similar layer, at approximately the same depth, and the quantity of water to be obtained was already known to be too small for our purpose. For the next 33 feet the drill went through the hardest kind of blue clay.

At a depth of 85 feet rock was reached. This was a hard sandstone, closely resembling fine granite.

An 8-inch wrought-iron pipe with a shoe upon the lower end, and in sections averaging 10 feet in length, and fastened together by thread joints, was driven firmly down into the rock. The hammer was the trunk of a white oak-tree, about 22 inches in diameter at the larger end, and about 20 feet long.

The whole depth drilled was 975 feet. The rock consisted of alternating layers of sandstone, blue clay slate, coal slate, and quartzose conglomerate. There were eight layers of sandstone, seven of coal slate, seven of blue slate, two of quartzose conglomerate, and two that were a mixture of all. These layers varied in thickness, that is, in the direction of the drill, from 5 to 95 feet. As a core drill was not used, the thickness of the strata, of course, cannot be given with absolute scientific accuracy, but by examining every day the drillings which were brought up by the sand-pump, and by frequent measurings of the depth of the bore, it was possible to make a fair approximation to actual facts.

A diary was kept during the progress of the work, and specimens of the drillings preserved, representing every five or ten feet of the whole distance through which the drill passed.

One hundred and forty bottles of these samples are now labelled and put away in the office of the water commissioners. A duplicate set has been furnished the United States Geological Survey.

The sediment in the sand-pump was commonly of the consistency of sand. Sometimes rock chips as large as walnuts were drawn up.

During the driving of the pipe, work was continued for the ordinary ten hours a day. April 13, eight days from the start, rock was reached, and thereafter drilling was performed during the whole twenty-four hours.

At 7.30 P.M., Sunday, May 5, the surface of the water in the well was $16\frac{1}{2}$ feet below the surface of the ground. The depth of the well at this time was 270 feet.

At a depth of 305 to 317 feet a stratum of quartzose conglomerate was encountered. This for the most part was very hard, and dulled the bits so rapidly that very slow progress was made. In the midst of this stratum seemed to be a crevice of sand, which gave a great deal of trouble by falling into the well.

May 19, when the depth was 323 feet, the water was within 15 feet of the top, — a gain of one foot and four inches over the previous week.

From July 19 to August 2 a great deal of difficulty was encountered and very little progress was made. The bit descended into a crevice which had a tendency to make the hole crooked, and thus jam the tools and stop them. The bit was temporarily replaced by a reamer.

July 25, the whole string of tools was caught in the crevice and work stopped. Fishing tools were shipped from New York, and finally, on August 1, the lost tools were recovered and reaming resumed. In a day or two the hole was straightened and the drilling again advanced.

August 9, at 10 A.M., the water was 11 feet and 6 inches from the top, and the depth of the well about 562 feet.

From October 31 to November 12 the use of a reamer was necessary much of the time, on account of a troublesome crevice. In fact, on the latter date the reamer in use was broken, and work was stopped, until a new one was obtained.

December 1, the level of the water was $11\frac{1}{2}$ feet below the surface of the ground. It never rose higher than this without pumping. The depth of the well at this time was 950 feet, and the drill was in a coal slate.

December 5, drilling ceased and a final measurement was made of the depth of the well. This proved to be 975 feet. The last 25 feet had been through hard sandstone.

At this period neither party was anxious to pursue the experiment further. A pumping test was at once made, to determine the amount of water which the well could be depended upon to furnish. A 4-inch wrought-iron pipe, in lengths of 20 feet, with thread joints, the pipe ends coming together flush, was sunk to a depth of 420 feet, and a $3\frac{3}{4}$-inch working barrel placed at a depth of 400 feet.

The piston-rod of the pump was made of $1\frac{1}{4}$-inch wrought-iron pipe. Pumping began at 11 A.M., Thursday, December 5, and continued night and day until Thursday morning, December 12.

The result of the test, and of the whole experiment, can be best summed up in the following quotation from the last annual report of the water commissioners :—

"During the forenoon of the first day's trial, the pumping was forced to a speed, for a minute, which caused it to throw water at the rate of about 200,000 gallons in 24 hours. The Board were not satisfied that this test made by the contractor was conclusive. Accordingly, from time to time, during the progress of the pumping, various tests were made. In brief, the result of these tests, based upon the size of the pump, the length of stroke, the rate of speed, and the observed time and rate required to exhaust the water, convinced the commissioners that the capacity of the well would not exceed 75,000 gallons a day, and might, perhaps, be reckoned with safety at about 70,000 gallons in 24 hours. To obtain even this quantity would require a deep well pump.

"Although the Board had hoped that sufficient water might be produced from this well alone, to justify the expectation of a satisfactory addition to our supply by means of two or three more, this hope has not been realized.

"The well may, however, be, after all, of some use. If the mineral analysis proves to be what they anticipate, and means of pumping can be devised not too expensive, the commissioners may conclude that, by pumping directly into the pump well a colorless artesian water of good quality, which will amount in quantity to nearly 8 or 10 per cent. of the daily consumption, the water from the filter basin may, during the hot weather, be rendered more palatable."

Mr. Hawes.— What was the quality of the water?

Mr. Chace.— The quality is good.

Mr. Hawes.— I am rather glad to hear this paper, because the first reports we got down at Fall River were that they had struck water in Taunton in one well at the rate of five million gallons a day, and they were going to put in twenty of them, and we were going to sell out our water works in Fall River, and get a supply from Taunton (laughter), and they were going to take a contract to fill the Atlantic Ocean. (Laughter.) I have never been able to get at the real facts before, and I am glad to find them out now.

Mr. Allis.— May I ask the gentleman what the cost of the work was?

Mr. Chace.— It cost $7 a foot.

Mr. Allis.— The total cost?

Mr. Chace.— The total cost was about $8,000.

Mr. Holden.— I would suggest that perhaps you might get more water by blasting that well; do you think of doing so?

Mr. Chace.— That matter was thoroughly considered. Before the experiment ended I began to hedge. I anticipated the thing might be a failure, and I sent all over the country, to every place where I knew there was an artesian well, circulars asking about the depth of the well, how many gallons it yielded, what kind of rock strata was there, who did the drilling, whether the water was of good quality, and if they had shot the well, and if so what the result of it was. With regard to the effect of shooting a well, I found that about one time in three the explosion increased the water, but sometimes it diminished the supply. The well-drillers themselves who worked there were unwilling to take the risk of doing it, because there was so much material they thought might be likely to cave in and spoil the whole thing.

Mr. Holden.— I have blasted several wells of that kind, and all of them but one resulted in giving more water; I never knew of a case of its being less. I blasted one on the Hudson river, a well about 1,000 feet deep, for a paper-mill, where they wanted to get a large supply of pure water for making note-paper. The supply was very small indeed. I put in three charges of nitro-glycerine, 25 pounds to a charge, and it was successful, as I think they have since had all the water they needed. This depends a good deal, however, upon whether there are any water-bearing veins anywhere in the vicinity. If there are, a heavy explosive will sometimes open the veins so as to get a great deal more water. But I don't understand how the effect would be to close anything up so as not to get as much, unless the well caved in. It might do that, if it was in very soft material. But, ordinarily, it makes a large chamber wherever the explosive lies.

Mr. Chace.— I remember an account of a well where they had a fair amount

of water before the explosion took place, and afterwards they got nothing; and we had some caving material where we were, and it looked as if it was risky to undertake it.

Mr. Holden. — At the Lowell Hosiery Mills, in Lowell, they blasted a well some four or five years ago, and increased the flow very considerably by that.

Mr. Hawes. — There was a well driven in Fall River some six or seven hundred feet, and in going down they went through a very nice streak of plumbago; and when they got clear down, they blasted the well. Some five or six hundred citizens had gone down to see the blast, and when the explosion came it sent a column of about as inky-looking stuff as you would want to see 300 feet into the air. The five or six hundred citizens weren't quick enough in getting out of the way, and they got a pretty good dose. (Laughter.) We heard a great deal of what that well was going to do. They were going to demolish this monopoly of the water works (laughter); but we have never heard from it since. I don't know what they use the water for. It certainly isn't good enough for drinking, it is rather bad for engine boilers, and it is a little dark for washing, and what they use it for I don't know. (Laughter.) There have been four or five of these wells drilled in Fall River, but I don't know that any one of them has been put to any practical use. There is one at the brewery, — any water, you know, is good enough for beer (laughter), — and the man who drilled it didn't care how much money he spent, so every hundred feet he would send a sample of it down to Boston and have it analyzed. The last time I saw him he hadn't got it good enough, but he had got about as far down as he was going with it. He uses the water for washing his bottles, but not for making his beer. He continues to use our pond water to make his beer with. I haven't heard of a well yet which can be put alongside of any good pond supply. If anybody knows of any such, let us hear from him about it. (Laughter.)

Mr. Holden. — I have heard a good deal about an artesian well at Lawrence, at Stanley's brewery; perhaps Mr. Salisbury can tell us about that.

Mr. Salisbury. — I think you must be mistaken; I never have heard of any. The only well they have there spouts lager beer. (Laughter.)

Mr. Hyde. — Before we adjourn I might speak of a little experience I had a short time ago in painting and repacking some hydrants and flushing my mains. I had occasion to open a hydrant which is used for a blow-off. It was situated near a fence where the sun hardly struck it all day, so the casting was undoubtedly full of frost, and perhaps there was some air in the hydrant. The man who had the wrench opened the hydrant about three turns, and as soon as he did that, the hydrant blew out, and exploded with a report about as loud as a gun. The hydrant was blown all to pieces from the street level, so we picked it up in small pieces as large as your two hands. I found in examining the casting that there was a flaw on one side of the post where the iron was about three-eighths of an inch thick, for the length of about a foot, — a cold schut in the casting. But I presume the principal cause was, perhaps, some air and the frost in the iron, because the hydrant had been used for that purpose for two years. That may be a little experience some of the other members have not had. I had never had anything of the kind before.

Mr. Holden. — What kind of a hydrant was it?

Mr. Hyde. — It was the Carr supplementary hydrant.

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